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Systems Analysis Study of Solid Waste Collection Management. Volume 1. Reports on Network Coding, Network Selection and Information System Tasks

Wichita Falls Dept. of Public Works, Tex

Prepared for

Environmental Protection Agency, Washington, D.C.

1977

PB 276 707

SYSTEMS ANALYSIS STUDY
OF SOLID WASTE COLLECTION MANAGEMENT

Volume I

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for the Federal solid waste managment program
under grant no. S800279
and is reproduced as received from the grantee*

Volume I reports on network coding,
network selection, and information system tasks.

Volume II contains simulation tasks.

U.S. ENVIRONMENTAL PROTECTION AGENCY
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The objective of this study was to demonstrate the use of automatic techniques in supporting solid waste management. Automation techniques were demonstrated in two major areas:

- Resource scheduling, measuring, and reporting for management (Volume I)
- Operational simulation for evaluation of management strategies and options (Volume II)

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An environmental protection publication (SW-150.1) in the solid waste management series.

PREFACE

A Solid Waste Collection Study was initiated in Wichita Falls, Texas, in October, 1972. The objective of the project was to demonstrate the use of automation techniques in supporting solid waste management. Automation techniques were demonstrated in two major areas:

- (1) Resource scheduling, measuring, and reporting for management control; and,
- (2) Operational simulation for evaluation of management strategies and options.

The management control area encompassed three substantial tasks. They were:

- (1) The development and demonstration of automated techniques for coding a solid waste collection network;
- (2) The development and demonstration of automated techniques for selecting efficient collection routes through a network and optimizing resource assignments to collection routes; and,
- (3) The development and implementation of an automated solid waste management information system.

The simulation and strategy evaluation area encompassed two substantial tasks. They were:

- The development of a simulation model that will represent any of several solid waste collection environments.
- The demonstration of the model as a tool for evaluating management strategies and for developing collection system optimization recommendations.

The work effort and results of these five major project tasks are reported in the two volumes of this project final report. The network coding, network selection, and information system tasks are included in Volume I. The simulation tasks are in Volume II.

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INTRODUCTION
TO
VOLUME I

INTRODUCTION TO VOLUME I

In most cities solid waste collection and disposal are high cost activities making up 10% to 15% of the total municipal budget. A large, relatively unskilled, labor force is required. The work load varies substantially by day of week and season of year. Total work load and individual work rates are poorly defined. Performance measurements are largely unspecified thus efficiency levels are not determined and resource allocation projections are not made.

Solid waste managers have an urgent need for system control tools and management control information. This volume of the final report presents a set of system control tools that will allow a manager to:

- Balance collection crew workloads.
- Conveniently adjust resource allocations to match daily or seasonal variations in the workload.
- Consider pertinent daily operational information in identifying equipment and personnel problem areas.
- Consider weekly and annual operational summaries in projecting future disposal needs, personnel requirements, equipment requirements, and capital investment levels.

The control tools presented in this volume are:

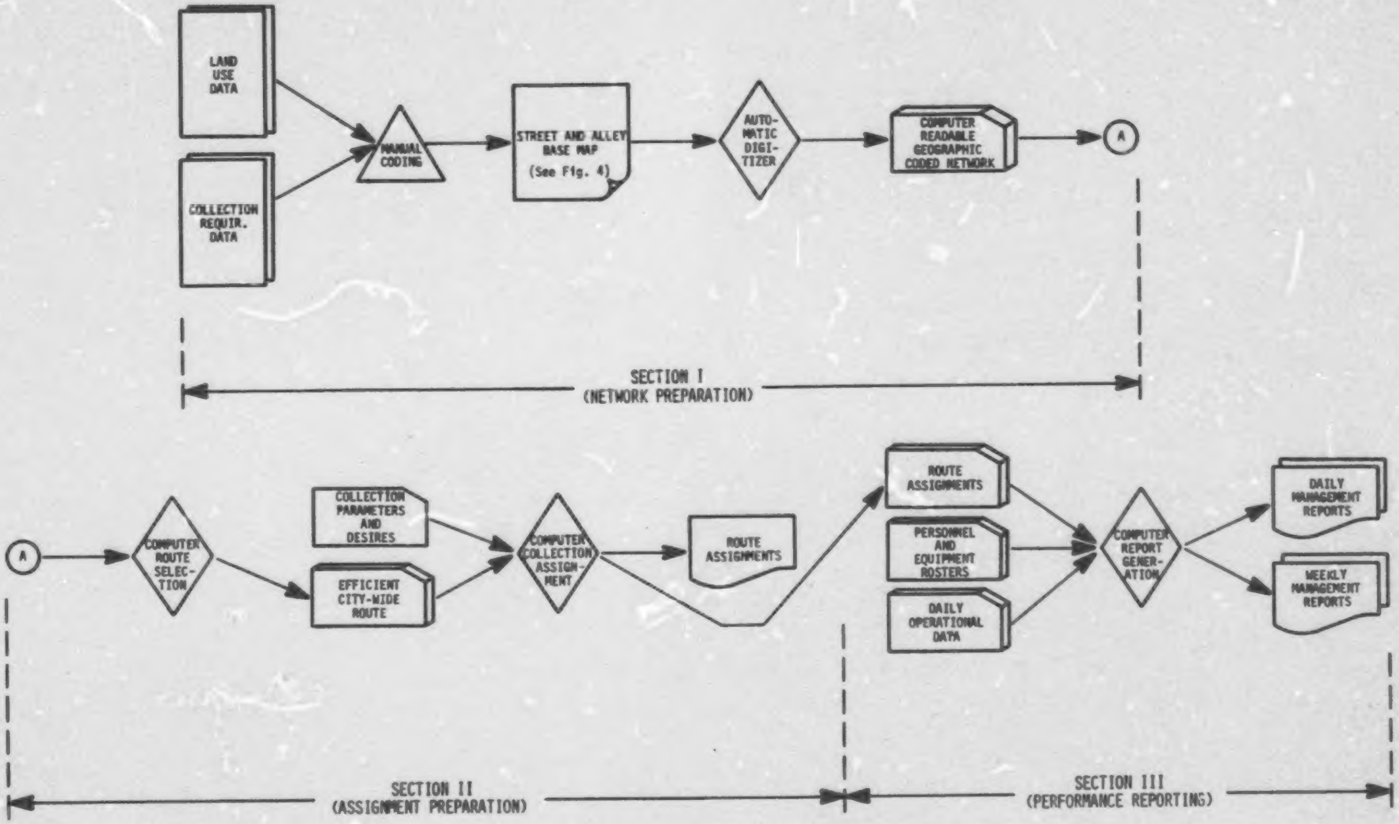
- A set of computer programs for selecting efficient collection routes
- A set of computer programs for partitioning the efficient routes into balanced one-day work segments based on daily and/or seasonal parameters
- A set of computer programs for processing operational data to produce daily and weekly management control reports

Each of these tools requires that the collection network be represented in a computer-readable form. This representation, if constructed manually is a tedious, costly, error-prone activity. This volume also presents an automated means of constructing the collection network representation.

The system control tools that have been developed are discussed in the order in which they will be utilized by a solid waste manager. The material to be presented is outlined as follows:

- Section One--Automated Techniques for Coding a Collection Network
- Section Two--Automated Techniques for Selecting an Efficient Collection Route and Balancing Route Assignments
- Section Three--Solid Waste Management Information System

A graphic overview of this volume and the material to be presented in each of the three sections is presented in Figure 1.


LAND USE DATA
COLLECTION REQUIR. DATA
MANUAL CODING
STREET AND ALLEY BASE MAP (See Fig. 4)
AUTO-MATIC DIGI-TIZER
COMPUTER READABLE GEOGRAPHIC CODED NETWORK
A
SECTION I (NETWORK PREPARATION)
A
COMPUTER ROUTE SELEC-TION
COLLECTION PARAMETERS AND DESIRES
EFFICIENT CITY-WIDE ROUTE
COMPUTER COLLECTION ASSIGN-MENT
ROUTE ASSIGNMENTS
ROUTE ASSIGNMENTS
PERSONNEL AND EQUIPMENT ROSTERS
DAILY OPERATIONAL DATA
COMPUTER REPORT GENER-ATION
DAILY MANAGEMENT REPORTS
WEEKLY MANAGEMENT REPORTS
SECTION II (ASSIGNMENT PREPARATION)
SECTION III (PERFORMANCE REPORTING)

GRAPHIC OVERVIEW OF VOLUME I

Figure 1

SECTION ONE

AUTOMATED TECHNIQUES FOR CODING A COLLECTION NETWORK

INTRODUCTION

The residential collection function is the major cost component of the municipal solid waste collection and disposal operation. Automated methods (discussed in the next section of this volume) have been developed to reduce residential collection cost by:

- Identifying and implementing collection routes that minimize non-collection travel

- Balancing resource assignments to work loads so that each collection crew accomplishes its equitable portion of the work task each day

These automated methods depend on an accurate, coded representation of the street and alley network utilized by the collection vehicles.

The basic elements of the coded network are illustrated in Figure 2. They are the link and the node. A link is a street segment or an alley segment which can be traversed by a collection vehicle. A node is the termination point of a link, usually the intersection of two or more links. Residences or businesses requiring solid waste collection are associated with the link used to service them.

Each node in a coded network is defined by a unique ID number and by a pair of geographic coordinates. Each link is defined by the two nodes which terminate the link. Each link is described by attributes such as length and surface type. Servicing requirements are described in terms of the land parcels to be serviced, and optionally, the general characteristics of the neighborhood such as average lot size or average floor space.

Manual encoding of the collection network is a slow, tedious, costly, error-prone task. The most common errors are:

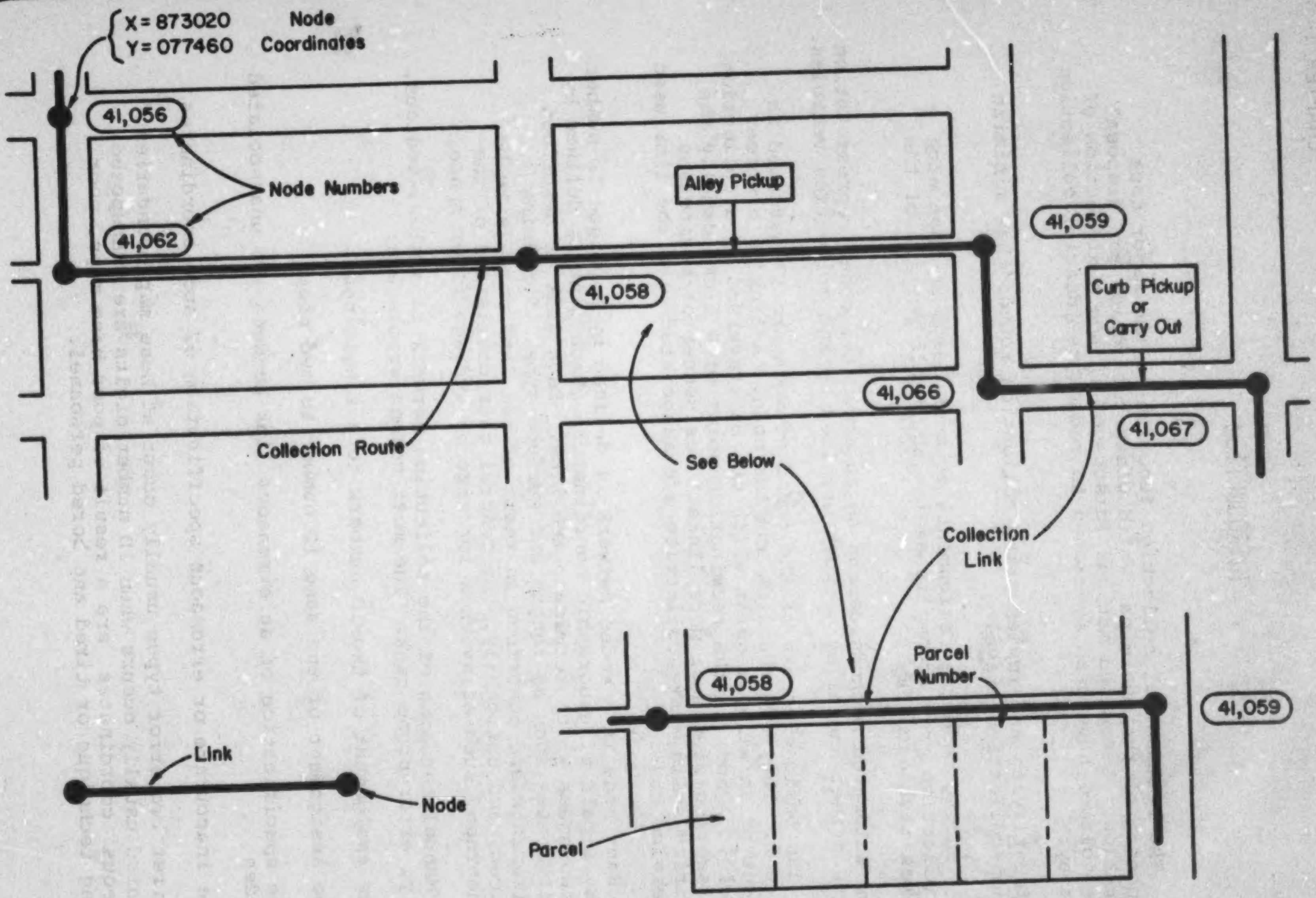
- The assignment of two ID numbers to a single node

- The assignment of the same ID number to two nodes

- The specification of an erroneous link between two unassociated nodes

- The inaccurate or erroneous specification of node coordinates

The first two error types usually occur at base map boundaries. The third usually occurs when ID number digits are transposed. Erroneous coordinates are a result of poor base maps, poor scaling technique or tired and bored personnel.


X = 873020
Y = 077460
Node Coordinates
41,056
Node Numbers
41,062
Collection Route
Alley Pickup
41,058
See Below
41,066
41,059
Curb Pickup or Carry Out
41,067
Collection Link
41,058
Parcel Number
41,059
Link
Node
Parcel

NETWORK CODING ELEMENTS

Figure 2

This section of this final report volume describes an automated digitizing method for encoding a solid waste collection network. The method, compared to the manual encoding method, is very fast, very accurate and much less expensive. Chapter II describes the automated procedure and illustrates the encoding results. The computer programs are described in Chapter III. Chapter IV presents an evaluation of the method and a comparison with manual encoding results.

16 blank

AUTOMATED PROCEDURE FOR CODING A NETWORK

The essential elements of the automated procedure are the digitizer and its associated mini-computer. The pilot study digitizing was performed on an Auto-Trol Model 3990 system. A Bendix Datagrid system, an H. Dell Foster RSS 4MGT system, and perhaps other systems, are also suitable for the digitizing task.

The Auto-Trol system is shown in Figure 3. The base map to be digitized is secured to the large inclined surface. The operator manipulates a cursor which is cable connected to a mini-computer. The cursors exact position is continuously sensed by an electronic grid associated with the inclined surface. As the cursor is positioned over each map node, the operator depresses a button which causes the X and Y coordinates of the cursor location to be transmitted to the mini-computer. The computer assigns a sequential unique ID number to the set of coordinates. It then punches the X coordinate, Y coordinate and ID number into a card. The information is also recorded on a magnetic disk storage device. The Auto-Trol system also includes a cable connected keyboard for supplemental data entry.

The automated network coding procedure encompasses seven separate steps. These steps are described below:

(1) A set of base maps of the street and alley system is manually prepared for digitizing by writing the following information on the maps for each link:

- Link type (street or alley)
- Link direction for one-way streets
- Number of residential units assigned to each collection link (for workload projections, commercial establishments receiving collection crew service are represented in residential unit equivalents)

Land use data items such as average floor space can also be recorded for each link or optionally for each map sheet.

The map sheets must be reasonably accurate. Typical city base maps at 1" = 200' or 1" = 400' are adequate. A sample of a prepared base map is shown in Figure 4.

(2) The prepared map is placed on the digitizer board. The operator digitizes the network nodes by:

- Placing the cursor over each map node
- Pressing a button which causes the X and Y coordinates of the cursor location to be punched into a card and written

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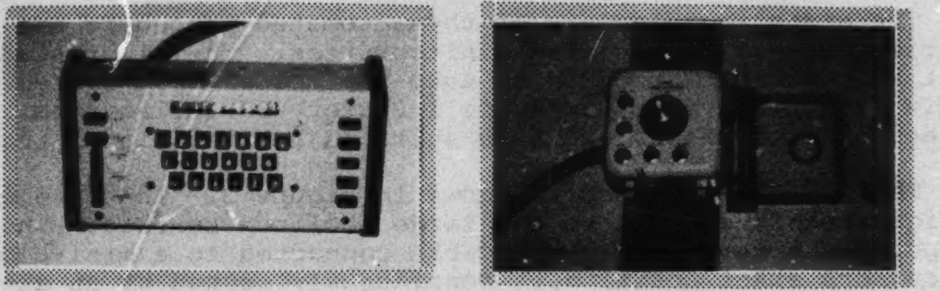
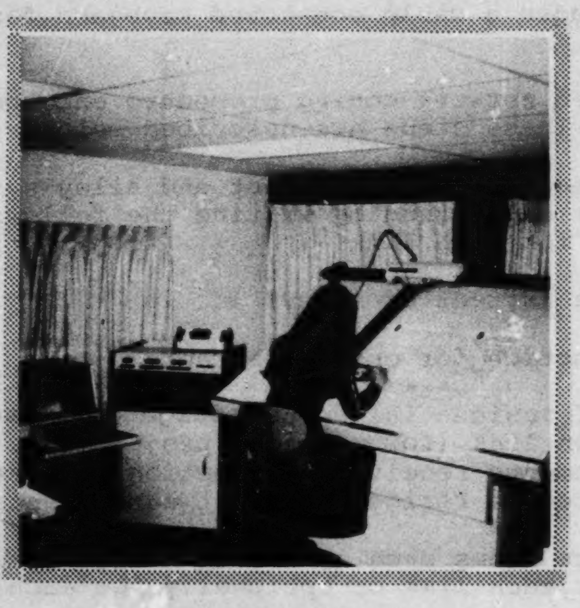


DATA ENTRY
KEYBOARD

CURSOR



DIGITIZER IN
OPERATION

DIGITIZING EQUIPMENT

Figure 3

on a magnetic disk. An automatically incremented sequence number (node ID number) is also punched and recorded for each node.

(3) The data cards are read by a computer program and a geographic plot of each node and its ID number, is made on an overlay map of identical scale to the base map. A sample overlay map is shown in Figure 5.

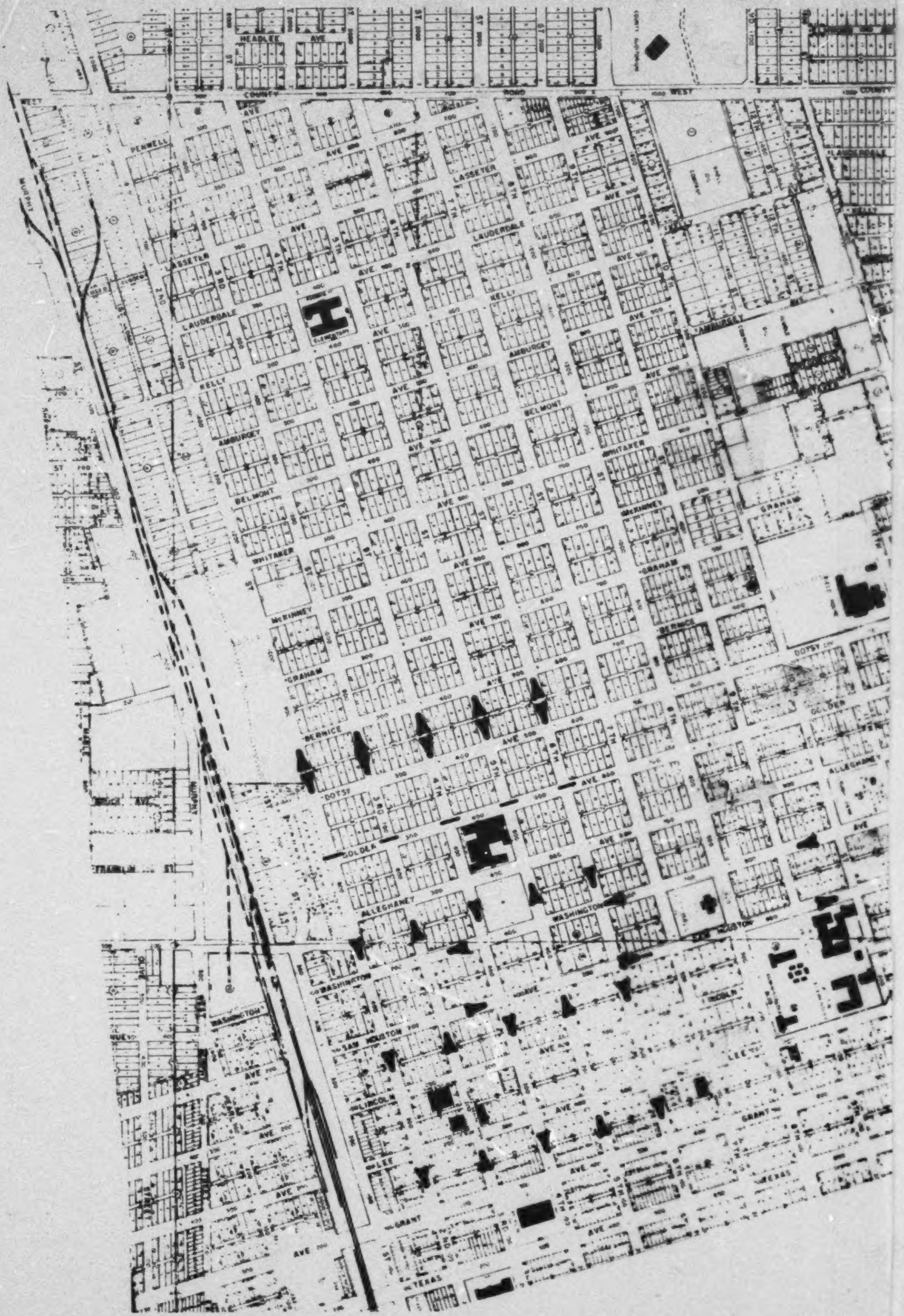
(4) The base map is placed on the digitizer board overlaid by the plotted map (see Figure 6). Using the data entry keyboard (see Figure 3), links are established by entering an A node ID, a B node ID and the data items (see Step 1) previously written on the map. As the data entry for each link is completed it is recorded on magnetic disk, then combined with the node coordinate information already on disk to produce a punched card for each link. A listing of the link cards is also produced. The format of the link cards produced in the pilot study is shown in Table 1. A sample of the produced listing is shown in Figure 7.

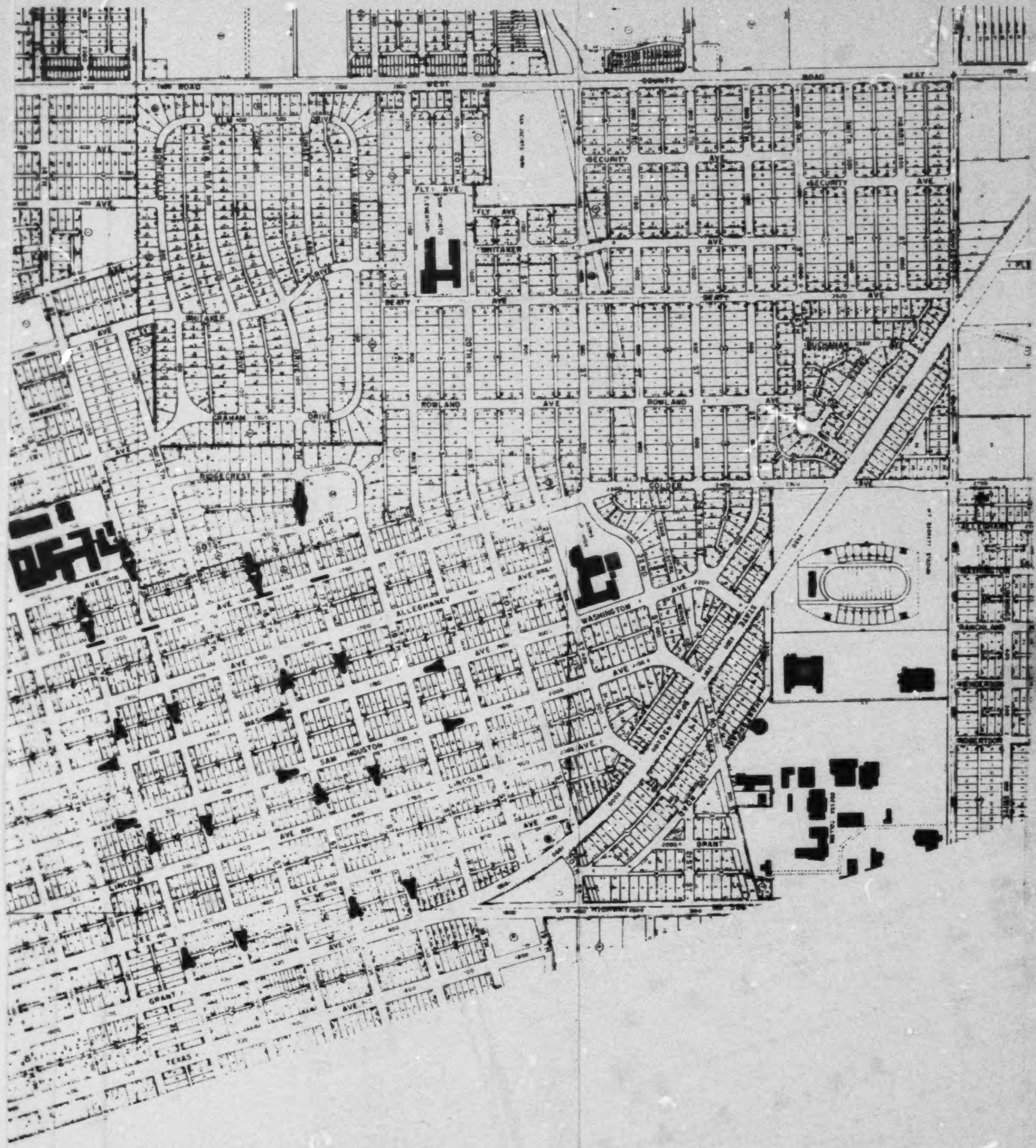
(5) The link cards are read by a computer program and the network is plotted on an overlay map. A sample overlay map is shown in Figure 8. Each node is represented by a small square, each non-collection link by a dashed line, and each collection link by a solid line. One-way-travel links are identified with arrowheads. Note on Figure 8 how easy it is to discover misconnected nodes and erroneously coded one-way-travel links. A listing of the network links is also produced. A sample of the listing is shown in Figure 9.

(6) The original base map and the plotted overlay are used to verify the coding of collection links, link direction, node location, number of residential units, etc.

(7) The link cards are corrected as necessary to establish an accurate, validated, coded network. The coded network then becomes input to the route selection and route balancing procedures discussed in Section Two of this volume.

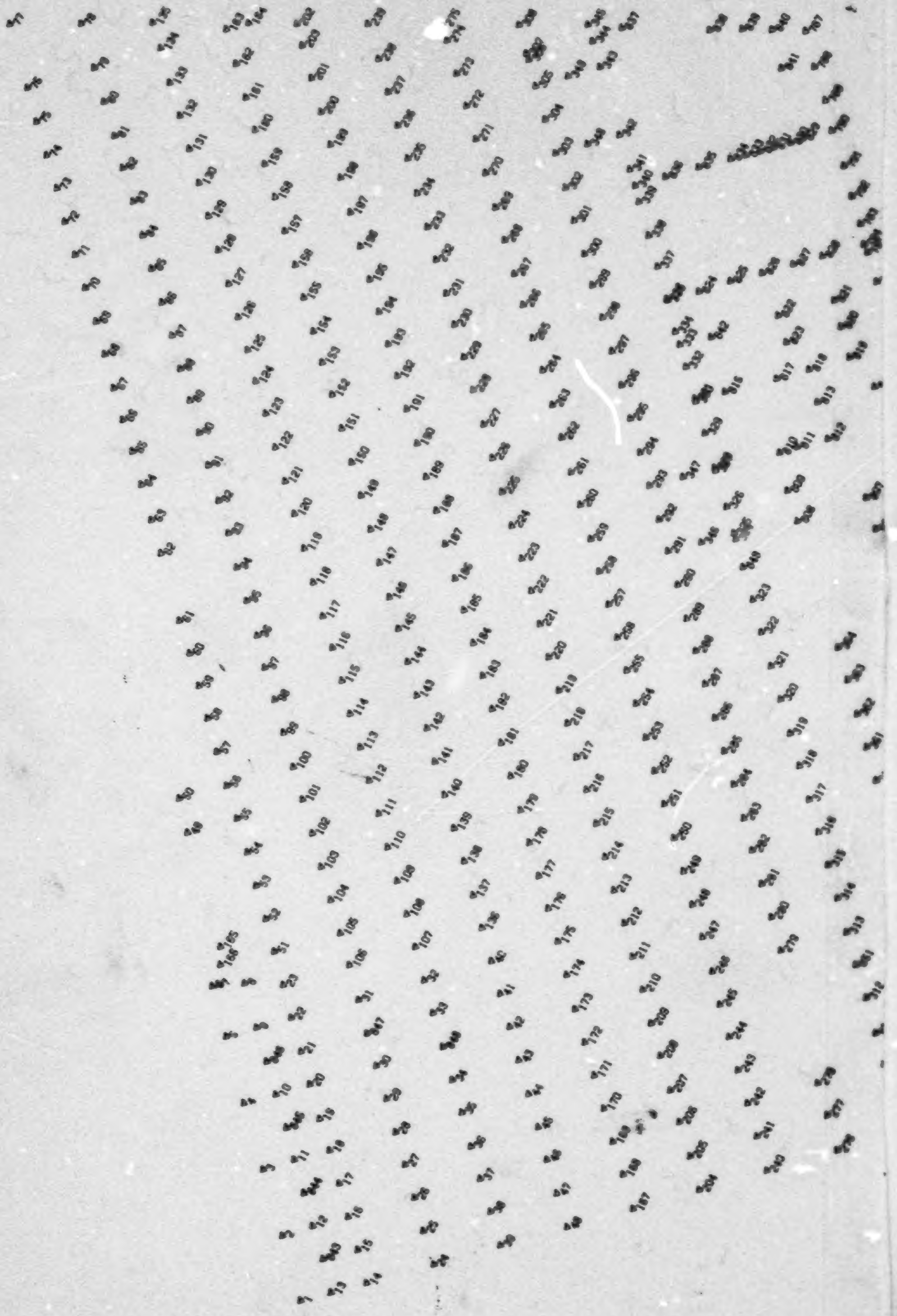
This seven step procedure is presented graphically in Figure 10. This detailed graphic conforms to the generalized graphic presented in the upper third of Figure 1.

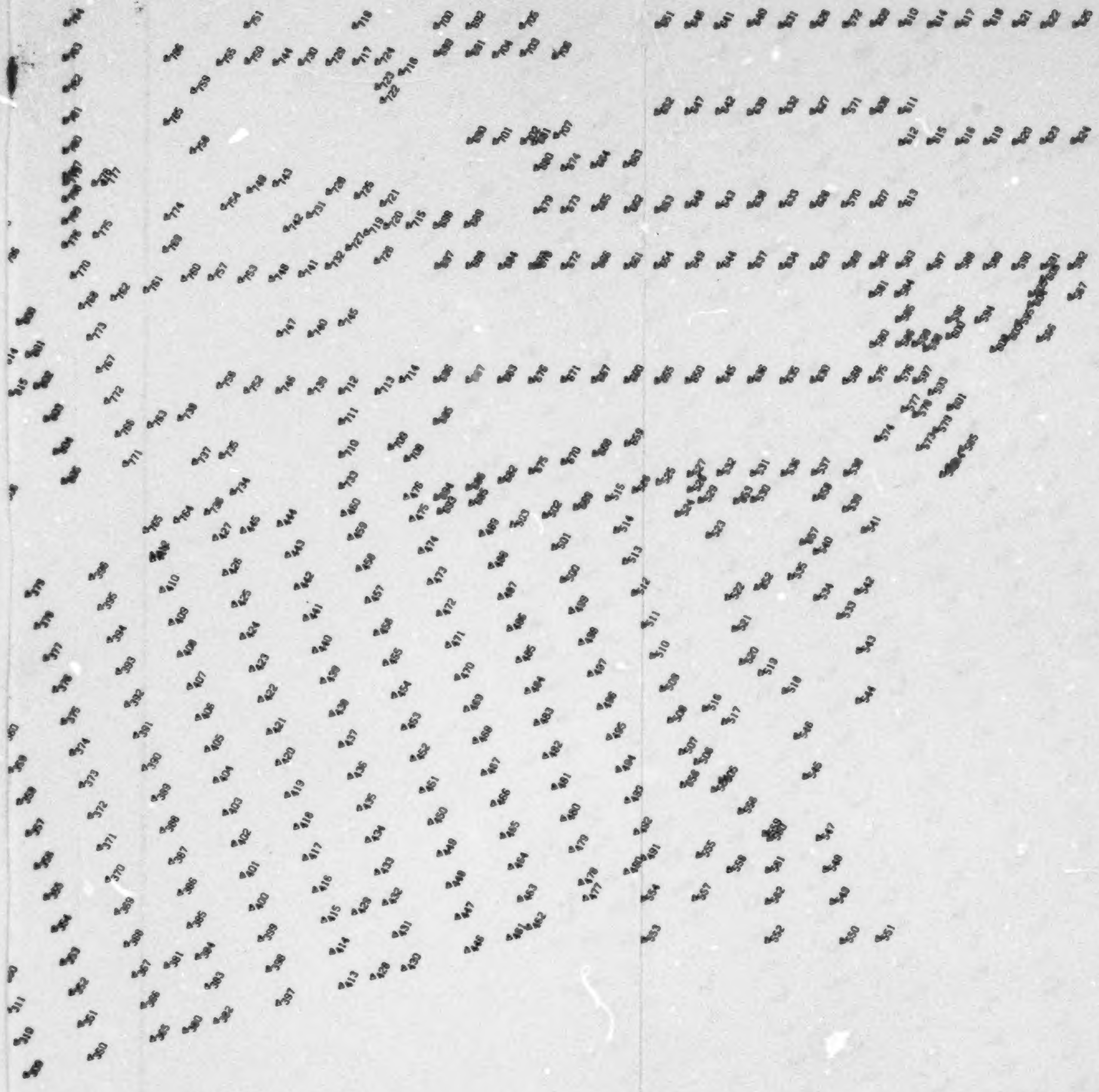

HEADLEE AVE
COUNTY ROAD WEST
PENWELL
ELLIOTT
LASSETER
LAUDERDALE
ELEMENTARY
KELLY
AMBURGEY
BELMONT
WHITAKER
McKINNEY
GRAHAM
BERNICE
DOTSY
GOLDER
ALLEGHANEY
WASHINGTON
SAN HOUSTON
LINCOLN
LEE
GRANT
TEXAS
FRANKLIN ST
AVE
ST


COUNTY ROAD WEST
SECURITY AVE
FLY AVE
WHITAKER
BEATY AVE
BUCHANAN
ROWLAND AVE
GRAHAM DRIVE
RIDGECREST
GOLDER
WASHINGTON
ALLEGHENEY
SAN HOUSTON
LINCOLN
LEE
GRANT
TEXAS
U.S. HIGHWAY

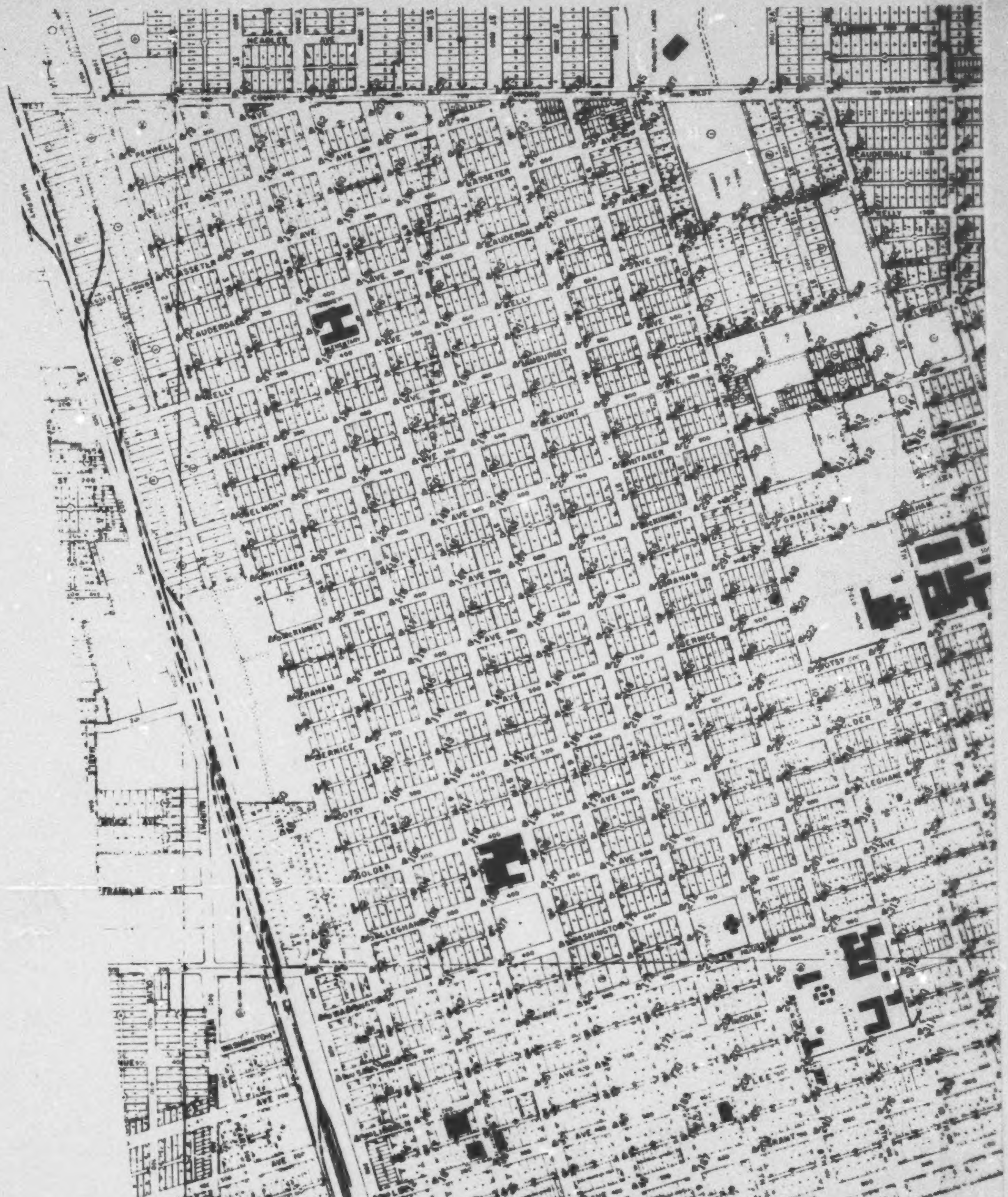
PREPARED BASE MAP
Figure 4

PINNELL-ANDERSON-WILSHIRE AND ASSOCIATES, INC.

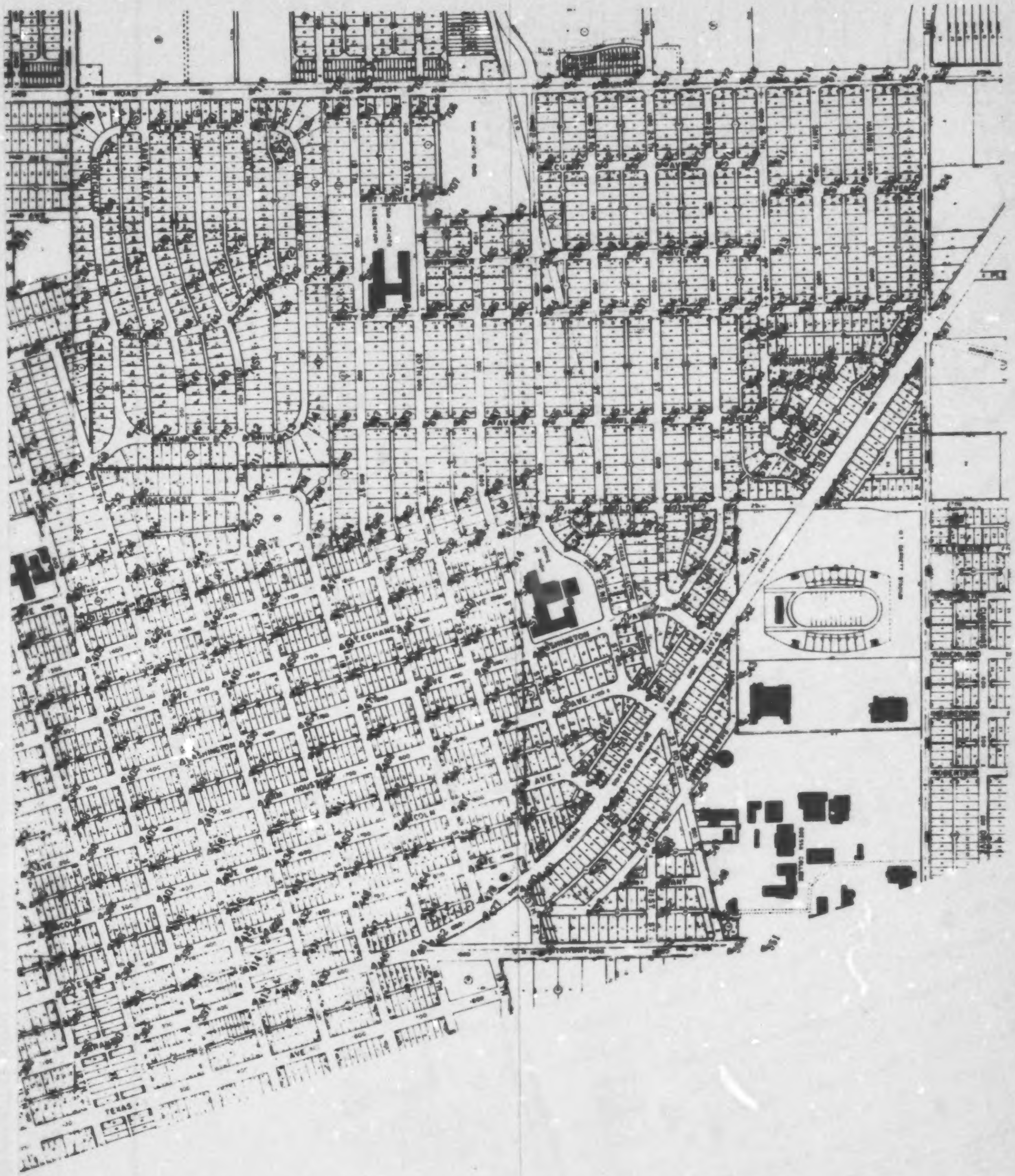




PLOTTED NODE OVERLAY MAP
Figure 5


HEADLEE AVE
COUNTY
WEST
MURPHY
PENNELL
ELLIOTT
LASSETER
LAUDERDALE
KELLY
BELMONT
WHITAKER
McKINNEY
GRAHAM
BERNICE
HOLDER
ALLEGHANY
WASHINGTON
FRANKLIN ST
LINCOLN
LEE
GRANT
TEXAS
AVE
ST

(24)



OVERLAY SUPERIMPOSED
ON STREET NETWORK
Figure 6

(25)

(26) - blank

TABLE 1. LINK CARD FORMAT

COLUMNS	CONTENT
1-5	A Node ID
6-14	X Coordinate
15-23	Y Coordinate
24-28	B Node ID
29-37	X Coordinate
38-46	Y Coordinate
47-50	Link Distance (computed)
51	Link Direction (1 = one-way; 2 = two-way)
52	Link Surface (1 = paved; 2 = unpaved)
53	Link Class (1 = street; 2 = alley)
54	Collection Type (1 = one-side; 2 = two-side)
55-56	Number of Carry-outs
57	Carry-out Class (based on distance from curb)
58-61	Map Sheet Number
62	Network Area (collection area of City)
63-64	Number of Residential Units
65-68	Average Floor Area *
69-73	Average Income *
74-75	Average Persons Per Residential Unit *

* These items were entered one time for each map sheet, but were punched into each link card.

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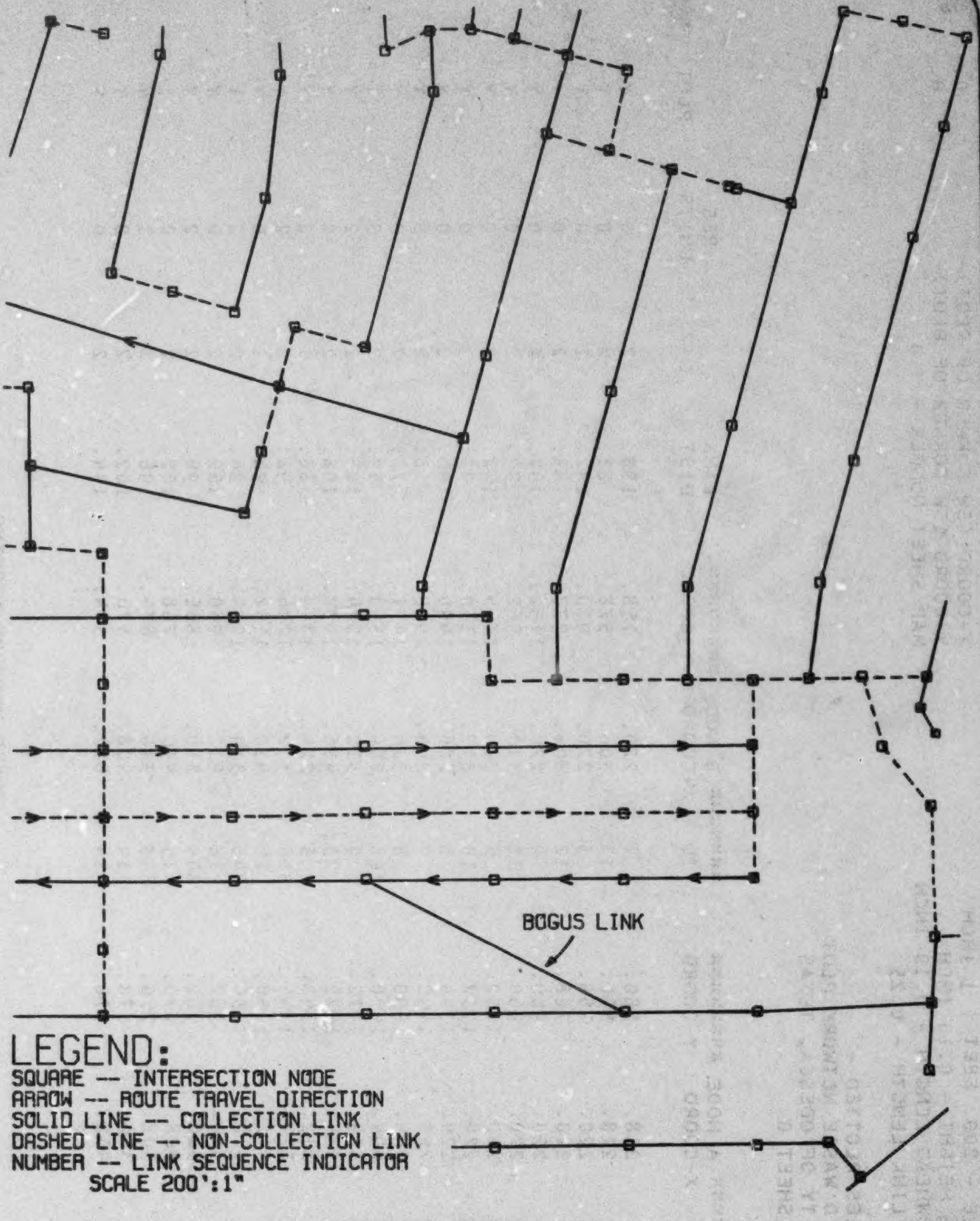
```
A-NODE   COORDINATES    B-NODE   COORDINATES     DIST                                  MAP              FLOOR  INCOME
(FROM)   -X-      -Y-    (TO)    -X-      -Y-   (FEET)  D  S  C  T   CO   CC   NO.  ST   RU  AREA   LEVEL   P/P

   1     218.    580.     13     306.    578.    88.    2  1  1  1   0    0    0    0    0    0       0.     0
   1     218.    580.      2     220.    768.   188.    2  1  1  1   0    0    0    0    0    0       0.     0
   2     220.    768.     12     308.    770.    88.    2  1  1  2   0    0    0    0    0    0       0.     0
   2     220.    768.      3     220.    960.   192.    2  1  1  2   0    0    0    0    0    0       0.     0
   3     220.    960.     11     310.    962.    90.    2  1  1  2   0    0    0    0    0    0       0.     0
   3     220.    960.      4     220.   1152.   192.    2  1  1  1   0    0    0    0    0    0       0.     0
   4     220.   1152.      5     224.   1344.   192.    2  1  1  1   0    0    0    0    0    0       0.     0
   4     220.   1152.     10     312.   1150.    92.    1  1  1  2   0    0    0    0    0    0       0.     0
   5     224.   1344.      9     312.   1344.    88.    1  1  1  2   0    0    0    0    0    0       0.     0
   5     224.   2344.      6     226.   1490.   146.    2  1  1  1   0    0    0    0    0    0       0.     0
```

COMPUTER LISTING OF DIGITIZED NODES

Figure 7

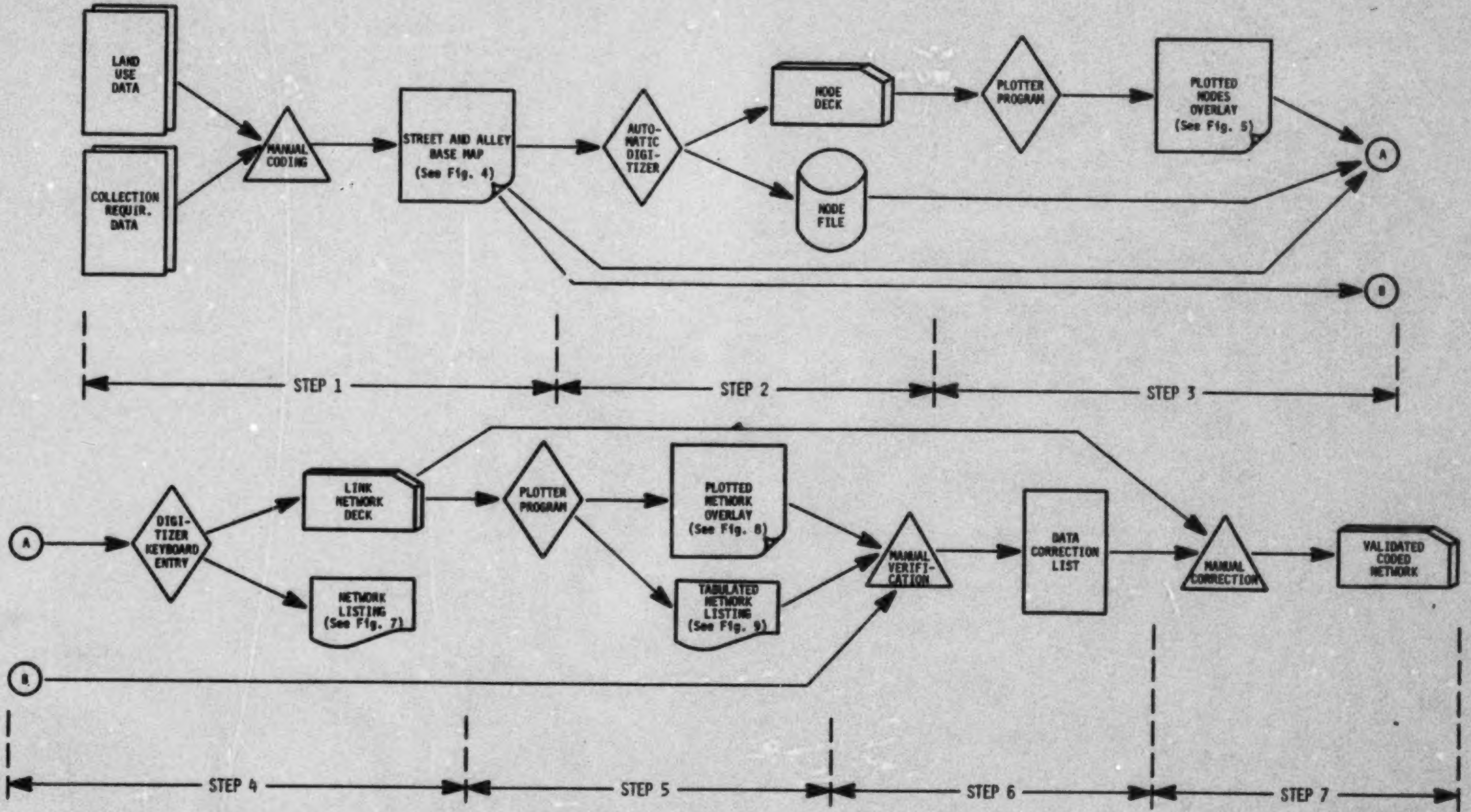

BOGUS LINK
LEGEND:
SQUARE -- INTERSECTION NODE
ARROW -- ROUTE TRAVEL DIRECTION
SOLID LINE -- COLLECTION LINK
DASHED LINE -- NON-COLLECTION LINK
NUMBER -- LINK SEQUENCE INDICATOR
SCALE 200':1"

NETWORK OVERLAY MAP
Figure 8

```
INPUT PARAMETERS -

SCALE - 200. FEET : 1 INCH                              X-COORD (SW CORNER OF PLOT)-          0.
NODE HEIGHT - 0.10 INCH                                 Y-COORD (SW CORNER OF PLOT)-          0.
ARROWHEAD LENGTH - 0.10 INCH                            MAP SHEET NUMBER -    0
MIN LINK LENGTH - 0.25

TITLES PLOTTED -
SOLID WASTE NETWORK PLOT
  CITY OF ODESSA, TEXAS
MAP SHEET 0

******* A NODE ********       ******* B NODE ********     LINK                RES
 ID    X-COORD    Y-COORD        ID   X-COORD   Y-COORD     DIST      DIR     UNITS      PLOT

  1     218.       580.          2     220.       768.      188.       2        0          Y
  1     218.       580.         13     306.       578.       88.       2        0          Y
  2     220.       768.          3     220.       960.      192.       2        0          Y
  2     220.       768.         12     308.       770.       88.       2        0          Y
  3     220.       960.          4     220.      1152.      192.       2        0          Y
  3     220.       960.         11     310.       962.       90.       2        0          Y
  4     220.      1152.          5     224.      1344.      192.       2        0          Y
  4     220.      1152.         10     312.      1150.       92.       1        0          Y
  5     224.      1344.          6     226.      1490.      146.       2        0          Y
  6     226.      1490.          7     244.      1490.       18.       2        0          Y
  7     244.      1490.          8     314.      1472.       72.       2        0          Y
  7     244.      1490.        166     264.      1540.       54.       2        0          Y
  8     314.      1472.          9     312.      1344.      128.       2        2          Y
  8     314.      1472.         23     416.      1438.      108.       2        0          Y
  9     312.      1344.          5     224.      1344.       88.       1        0          Y
  9     312       1344.        846     312.      1246.       98.       2        2          Y
 10     312.      1150.         20     410.      1152.       98.       1        0          Y
 10     312.      1150.        845     314.      1054.       96.       2        2          Y
 11     310.       962.         18     412.       960.      102.       2        0          Y
 11     310.       962.        844     310.       866.       96.       2        2          Y
 12     308.       770.         16     410.       768.      102.       2        0          Y
 12     308.       770.        843     310        674.       96.       2        1          Y
 13     306.       578.         14     408.       576.      102.       2        0          Y
 14     408.       576.         24     602.       574.      194.       2        0          Y
```

CODED NETWORK LISTING

Figure 9


LAND USE DATA
COLLECTION REQUIR. DATA
MANUAL CODING
STREET AND ALLEY BASE MAP (See Fig. 4)
AUTO-MATIC DIGI-TIZER
NODE DECK
NODE FILE
PLOTTER PROGRAM
PLOTTED NODES OVERLAY (See Fig. 5)
A
B
STEP 1
STEP 2
STEP 3
A
DIGI-TIZER KEYBOARD ENTRY
LINK NETWORK DECK
NETWORK LISTING (See Fig. 7)
PLOTTER PROGRAM
PLOTTED NETWORK OVERLAY (See Fig. 8)
TABULATED NETWORK LISTING (See Fig. 9)
B
MANUAL VERIFI-CATION
DATA CORRECTION LIST
MANUAL CORRECTION
VALIDATED CODED NETWORK
STEP 4
STEP 5
STEP 6
STEP 7

AUTOMATED CODING PROCEDURE

Figure 10

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COMPUTER PROGRAMS

The automated procedure diagrammed in Figure 10 has four automated steps. Each step utilizes one or more computer programs. The programs used in steps 2, 3, and 4 are the property of the digitizing service bureau. They are not described in this report. The programs utilized in step 5, to produce the plotted network overlay, were developed as a part of this demonstration project. These programs are described below.

The link network deck is read by a program written in G level FORTRAN IV for an IBM System/360 computer. The program calls numerous plotter command subroutines developed originally by the Cal-Comp Corporation. The purpose of this program is to produce plot commands which can be used to produce an overlay representation of the coded network.

The program represents each node by a small square. Each non-collection link is represented by a dashed line connecting two nodes. Each collection link is represented by a solid line. A one-way link, either collection or non-collection, is identified by an arrowhead at the midpoint of the link.

The program accepts several input parameters by which the user can specify:

- the size of the node square
- the length and width of the arrowheads
- the scale of the plotted map

An arrowhead on a very short link could overlap the node symbol, thus the user can specify the shortest link that should accomodate an arrowhead. The user can also specify a map sheet number. Plotting will be restricted to link records containing the specified map number. If the network is represented on several map sheets, this option allows the plotting of a single sheet without segmenting the input data.

The parameters are entered on a single card whose format is presented in Table 2. The program accepts two other input formats. The parameter card is followed by an unspecified number of title cards which are followed by an unspecified number of network link cards. The format of the title cards is presented in Table 2. The link card format is presented in Table 1. Examples of title plotting and network plotting symbols are presented in Figure 8.

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TABLE 2. NETWORK PLOT PROGRAM CARD FORMAT

CARD TYPE	COLUMNS	CONTENT	REMARKS
Parameter	1	Card ID	"p"
	2-5	Plot Scale	In ft per in.
	6-14	X Coordinate of S/W Corner of Map	In ft
	15-23	Y Coordinate of S/W Corner	In ft
	24-25	Height of Node Square	In hundredths of an in.
	26-27	Length of Arrowhead	In hundredths of an in.; zero inhibits arrowhead plotting
	28-29	Link Distance below which Arrowhead Plotting will be Inhibited	In hundredths of an in.
	30-33	Map Sheet Number	If blank or zero, all links are plotted
Title	1	Card ID	"T"
	2-3	Height of Plotted Letters	In hundredths of an in.
	4-12	X Coordinate of Lower Left Corner of First Letter	In ft
	13-21	Y Coordinate of Lower Left Corner	
	22-23	Number of Letters in Title	Including blanks
	24-79	Text of Title	
Link	(See Table 1)		

The program produces plotter commands and a listing of the network links. The listing is illustrated in Figure 9. The input parameter and the plotted title are presented at the top of the listing. The DIR column indicates one-way or two-way links, the PLOT column indicates whether a link was plotted (Y) or not plotted (N) based on a test of the map sheet number.

The plotter commands are written on a magnetic tape. This tape is then read by a NOVA computer which drives a Gerber plotter. The NOVA program accepts all plotter commands generated by the System 360 plot subroutines. The NOVA program is written in assembly language.

EVALUATION OF THE AUTOMATED METHOD

FEASIBILITY TEST

As a first step in the evaluation of the automated digitizing procedure a small scale feasibility test was conducted. A solid waste collection area, shown in Figure 11, of Wichita Falls was selected. The test area contained 84 links and 55 nodes. A base map was prepared by recording on the map residential units for each link. There were no one-way links in the test area.

The map was digitized (steps 2, 3, and 4 discussed in Chapter II) using a Auto-Trol Model 3990 digitizer system. The three steps were accomplished by an experienced operator in a total of 58 minutes. Average times were 19.6 seconds per node for digitizing and plotting, 46.4 seconds per link for digitizing.

The cost for this three step process was $44.13 plus an additional one-time-charge of $330.00. The latter charge was for developing the computer programs which accomplished the node plotting and the link data merging.

PILOT TEST

Odessa Area

As a second major step in the evaluation process, a larger geographic area was chosen for a pilot test. The selected pilot area encompassed about 1/6 of the City of Odessa, Texas. (See Figure 4.)

The entire Wichita Falls network had been coded manually. All base map errors and coding peculiarities had been discovered. The project team felt that for an objective evaluation, the pilot test should be conducted on a network that had not previously been coded. Odessa was chosen because of geographic similarities to Wichita Falls, because of an amiable relationship between Wichita Falls administrators and Odessa asministrators, and because Odessa possessed a good set of base maps.

The pilot test encompassed 853 nodes and 1472 links. The three step digitizing and plotting process required 22 work hours. The total cost was $419.50. Details of the work hours and costs are presented in Table 3.

Wichita Falls Projection

The pilot test network was represented on one map sheet (1" = 400'). The times per node and times per link presented

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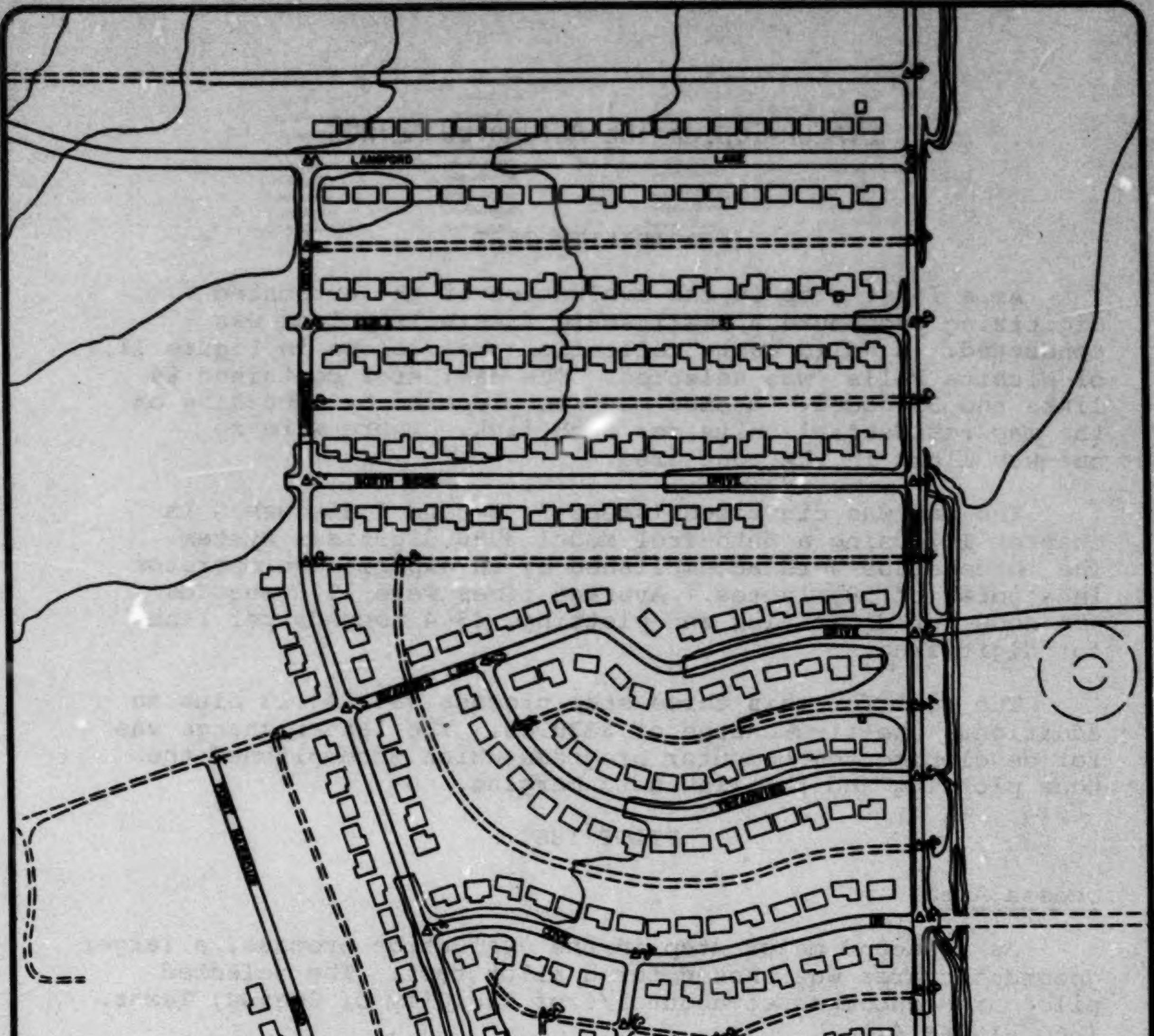
LANGFORD
LANE

WICHITA FALLS FEASIBILITY TEST AREA
Figure 11

TABLE 3. COSTS AND TIMES FOR DIGITIZING A COLLECTION NETWORK

ITEM	ODESSA PILOT TEST	WICHITA FALLS PROJECTION
Number of nodes	853	6000
Number of links	1472	10000
Node digitizing time	4.17 hr	29.33 hr *
Node plotting time	0.50 hr	3.50 hr *
Link digitizing time	17.25 hr	117.22 hr *
Total network time	21.92 hr	150.05 hr
Digitizing time per node	17.6 sec	17.6 sec
Plotting time per node	2.1 sec	2.1 sec
Digitizing time per link	42.2 sec	42.2 sec
Node digitizing cost (at $21/hr)	$87.50	$618.00**
Node plotting cost (at $76/hr)	$38.00	$270.00**
Link digitizing cost (at $21/hr & $8/hr)	$294.00	$2000.00**
Total network cost	$419.50	$2888.00
Digitizing cost per node	10.3¢	10.3¢
Plotting cost per node	4.5¢	4.5¢
Digitizing cost per link	20.0¢	20.0¢

* Projections based on average time per link and per node.
** Projections based on average cost per link and per node.

in Table 3 should then be applicable rates for a larger network of multiple map sheets. The rightmost column of Table 3 presents time and cost projections for the City of Wichita Falls (10,000 links and 6,000 nodes).

Total work hours are estimated to be 150 hours, or a little less than one man-month. Total cost is estimated to be $3,000. Add to this:

- Approximately one man-month (at $1,000/month) for preparing base maps (step 1 of Chapter II)
- Approximately one man-month (at $1,000/month) for validating and correcting data (steps 6 and 7 of Chapter II)
- Approximately $500.00 for computer time and plotter time in step 5

The estimated total cost for digitizing and validating the street and alley system of a city the size of Wichita Falls is $5,500. The estimated total effort is three man-months. The estimated project calendar time is three months.

MANUAL PROCEDURES

In a previous study, the street and alley network of the City of Wichita Falls was coded using manual procedures. This effort is described in pages 7-11 of Volume I of the June, 1971 Final Report of Project G06-EC-00135. Coding and validating the Wichita Falls network using manual procedures required about two man-years at a cost of approximately $25,000. Calendar time for the effort was about one year although coding errors are still occasionally discovered. With experience gained on the Wichita Falls effort, the project team estimates that a future network of similar size could be coded and validated manually in about nine months at a cost of $20,000.

CONCLUSIONS

The automated procedures for coding a street and alley network have been tested and found feasible. Comparing the automated procedures and the manual procedures for network coding and validation, the evaluation is as follows:

- The automated procedure requires about 1/8 of the effort
- The automated procedure is about 1/4 as costly
- The automated procedure results in significantly fewer errors in the completed network

Thus, on the basis of this comparison, the automated procedures are more cost-effective than the manual procedures used previously.

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It is the conclusion of this study and the recommendation of the project team that the automated procedures form an economic and effective method of coding a street network. The project team further concludes that the benefits of a coded network to a solid waste administrator far outweigh the cost of automated network coding. Some of the beneficial products of the network are presented in Sections Two and Three of this volume.

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SECTION TWO

AUTOMATED TECHNIQUES FOR SELECTING AN EFFICIENT COLLECTION ROUTE AND BALANCING ROUTE ASSIGNMENTS

INTRODUCTION

Productivity in solid waste collection depends on the efficiency and balance of collection routes. Efficient, well-balanced collection routes minimize non-collection and delay times, and provide for an equitable distribution of workload among collection crews. Automated techniques which have been developed during the course of this study for designing efficient, well-balanced collection routes are presented in this section.

The automated techniques constitutes a heuristic-deterministic approach as defined by Shuster and Schur.(1) However, used in conjunction with the automated network coding techniques presented in Section One, the disadvantage of costly, time-consuming, error-prone data preparation normally associated with the heuristic-deterministic approach does not exist. Consequently, the advantages of computer analysis can be more economically realized in collection route design.

Also, the computer programs used are based on manual procedures that are easily understood by solid waste managers. Thus, this particular heuristic-deterministic approach should not mystify the routing problem. Instead, it enables solid waste managers to more readily consider the impact of changes in collection systems and conditions on routing.

The automated routing techniques developed are utilized in a two-phase, route design procedure as follows:

- Route selection
- Route evaluation

During route selection, an efficient continuous route through a collection network is found. Then, during route evaluation, the continuous route is divided into efficient, well-balanced collection routes. The objectives, data requirements, procedures, computer programs, and demonstration of these phases are discussed in this section. Route selection is presented in Chapter II, and route evaluation in Chapter III.

ROUTE SELECTION

OBJECTIVE

The objective of route selection is to find a continuous route through a collection network that minimizes non-collection time and certain delay times. The route selection procedure determines a single continuous route that includes all collection links and a minimum of non-collection links. In addition, it prohibits or limits the necessity of certain delay causing manuevers such as left turns, U-turns, and backing. The continuity of the route selected facilitates route evaluation and implementation.

NETWORK DATA REQUIREMENTS

The route selection procedure requires a computer readable geographic coded network. The required network data is a deck of link cards that describes each link in the collection network. The following data are needed for each link:

- A node ID and X-Y coordinates
- B node ID and X-Y coordinates
- Link distance
- Link direction (1 = one-way; 2 = two-way)
- Link surface (1 = paved; 2 = unpaved)
- Link class (1 = street; 2 = alley)
- Collection type (1 = one-side; 2 = two-side)
- Network area (collection area of the city)
- Number of residential units

These data are provided by the automated network coding techniques presented in Section One. However, if the network data is not prepared using the automated network coding techniques, the network data should be edited to ensure that:

- The network is closed.
- There are not any duplicate node ID's.
- Data fields are correct.

The link card format for these data is the same as that shown in Table 1 of Section One.

PROCEDURE

The route selection procedure, which finds an efficient continuous route through a collection network, consists of the following steps:

(1) The link cards which define the collection network are sorted by network area. Network areas are collection areas of a city that are designated in the first step of the automated network coding procedure described in Section One. The collection network of a city is divided into collection areas that conform to man-made and natural network barriers such as major streets, expressways, railroads, parks, open spaces, rivers, lakes, gullies, hills, and mountains. This division of the collection network helps to ensure that:

- Routes will be compact and not fragmented or overlapping.
- Route crossings of network barriers will be minimized.
- Extremely long and unnecessary non-collection distances will be avoided.

In addition, division of the collection network into collection areas can significantly reduce the computer time required by the route selection program, because its run time varies exponentially with the number of links in the network being processed. Experience in Wichita Falls indicates that excessive run times can be avoided if the number of links in a network is less than 3000. The division of the Wichita Falls collection network is shown in Figure 12.

(2) The link cards of each network area are edited to ensure that each network is closed.

(3) Each set of network area link cards is input to the route selection program to find an efficient continuous route through each network area. The route selection program outputs a description of a continuous route in the form of a route deck composed of the appropriate sequence of link cards each containing the following link data:

- A node ID
- B node ID
- Link type indication (blank = collection; N = non-collection)

The route deck together with the original set of link cards is input to a computer program that produces a new continuous route deck composed of the appropriate sequence of link cards each containing the original link card data shown in Table 1 of Section One.

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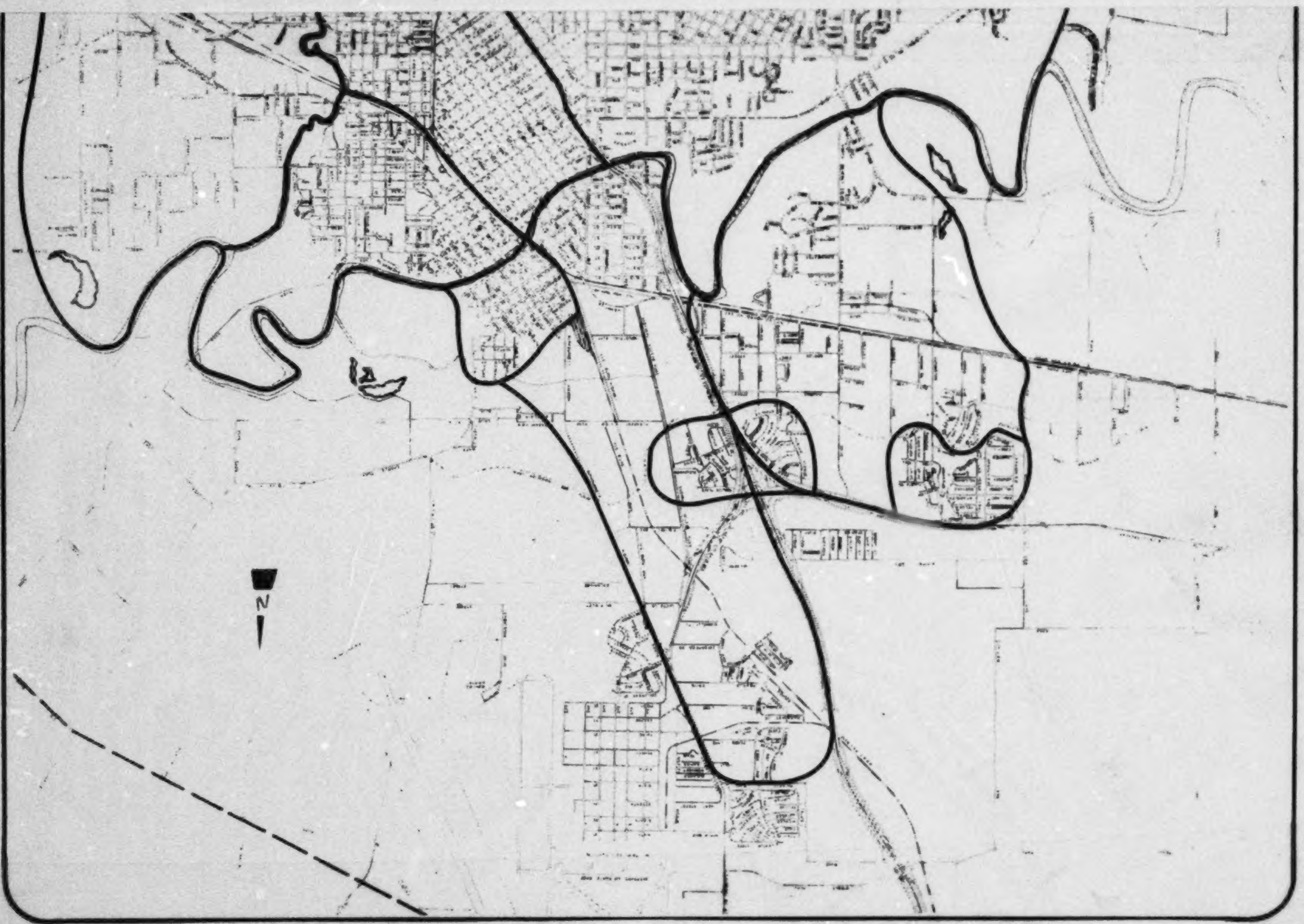
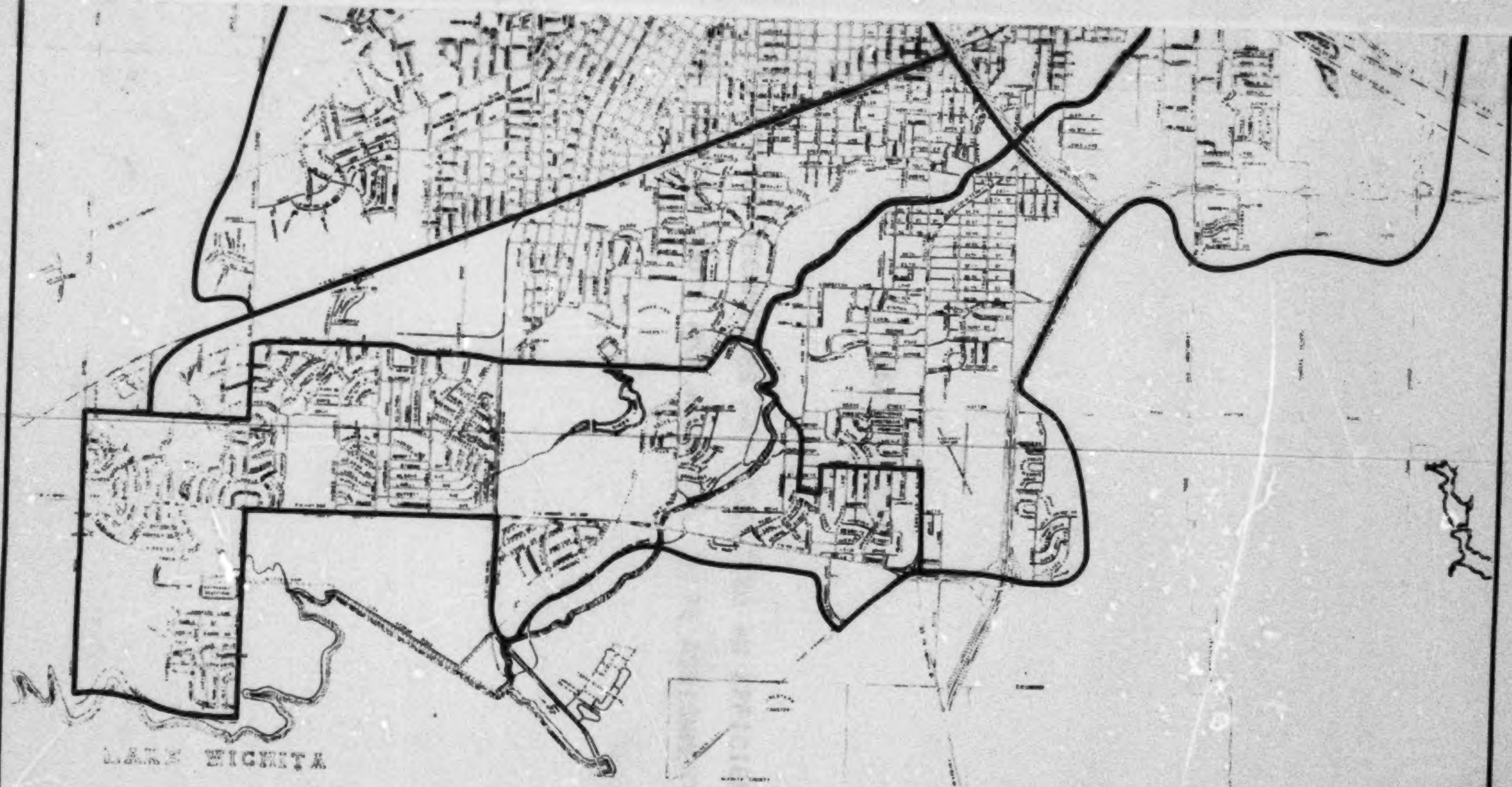

N



DIVISION OF WICHITA FALLS COLLECTION NETWORK INTO NETWORK AREAS FOR ROUTE SELECTION

Figure 12

PINNELL - ANDERSON - WILSHIRE AND ASSOCIATES, INC.

However, before the continuous routes can be selected for each network area, the beginning point for each route must be specified as input to the route selection program. Since the continuous routes selected are to be tied together to form one continuous route for the entire collection network, the location of beginning points depends on the order in which the individual collection routes are to be combined. A knowledge of the particular collection network and system involved together with routing heuristics are used by the route designer to determine an order for combining these routes that would yield a single efficient continuous route. The following routing heuristics listed by Shuster and Schur(1) are applicable in determining such an order:

- The route should not be fragmented, but compact.
- The route should be started as close to the headquarters as possible, taking into account heavily traveled and one-way streets.
- Heavily traveled streets should not be collected during rush hours.
- It is best to start the route near the upper end of a one-way street, working down it through the looping process.
- When practical, steep hills should be collected on both sides of the street, working downhill.
- Higher elevations should be at the start of the route.
- For two-side collection, it is generally best to route with long, straight paths across the network before looping.

Thus, the beginning points are usually located on boundaries between network areas which are to contain adjacent segments of the overall continuous route. Although the choice of a beginning point can affect the amount of non-collection distance in the continuous route selected, this effect is normally of secondary significance in comparison to the impact of the practical considerations referred to above.

(4) The continuous route deck of each network area is input to the plot program, described in Section One, to plot the continuous route selected for each network area on a map overlay. The map overlay is then superimposed on a street network map and readily checked for any illogical wandering or doubling back. Manual adjustments are easily made to the continuous route by removing the unnecessary non-collection links from

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the route deck and modifying the link sequence accordingly. A plot of the continuous route selected for one of the network areas in Wichita Falls in shown in Figure 13.

(5) The continuous routes are combined into one continuous route for the entire collection network. Usually the ending point of one continuous route does not coincide with the beginning point specified previously of the continuous route which is to follow. If it does, the route decks of the two routes are simply added together in the proper sequence. If it does not, manual adjustments to the route decks are necessary in order to change the ending point and/or beginning point so that they do coincide. These adjustments merely involve adding, removing, and/or rearranging a few link cards. Once the route decks have been adjusted, they are added together in proper sequence to form the route deck of a single continuous route.

If the discrepancy between the locations of the ending point of one route and the beginning point of the following route is believed to be too great for ready manual adjustment, steps 3 and 4 of this procedure can be repeated for the network area in question using a more appropriate beginning point. However, this is normally not necessary because the manual adjustments required are usually minor.

(6) The single continuous route deck is input to the plot program to plot the single continuous route on a map overlay. The map overlay is superimposed on a street network map for final review. Desired revisions are made on the map and to the route deck accordingly.

The route selection procedure is presented graphically in Figure 14, which conforms to the computer-route-selection block of the generalized graphic presented in Figure 1 of Section One.

ROUTE SELECTION PROGRAM

The route selection program is the computer program used to find an efficient continuous route through a collection network. It was written as part of the original Wichita Falls solid waste study, and it is described in that study's final report.(2)

Initially, the route selection program was designed to simply select a path through a collection network that passes over all collection links at least once and contains a minimum of non-collection distance. However, it has since been modified to

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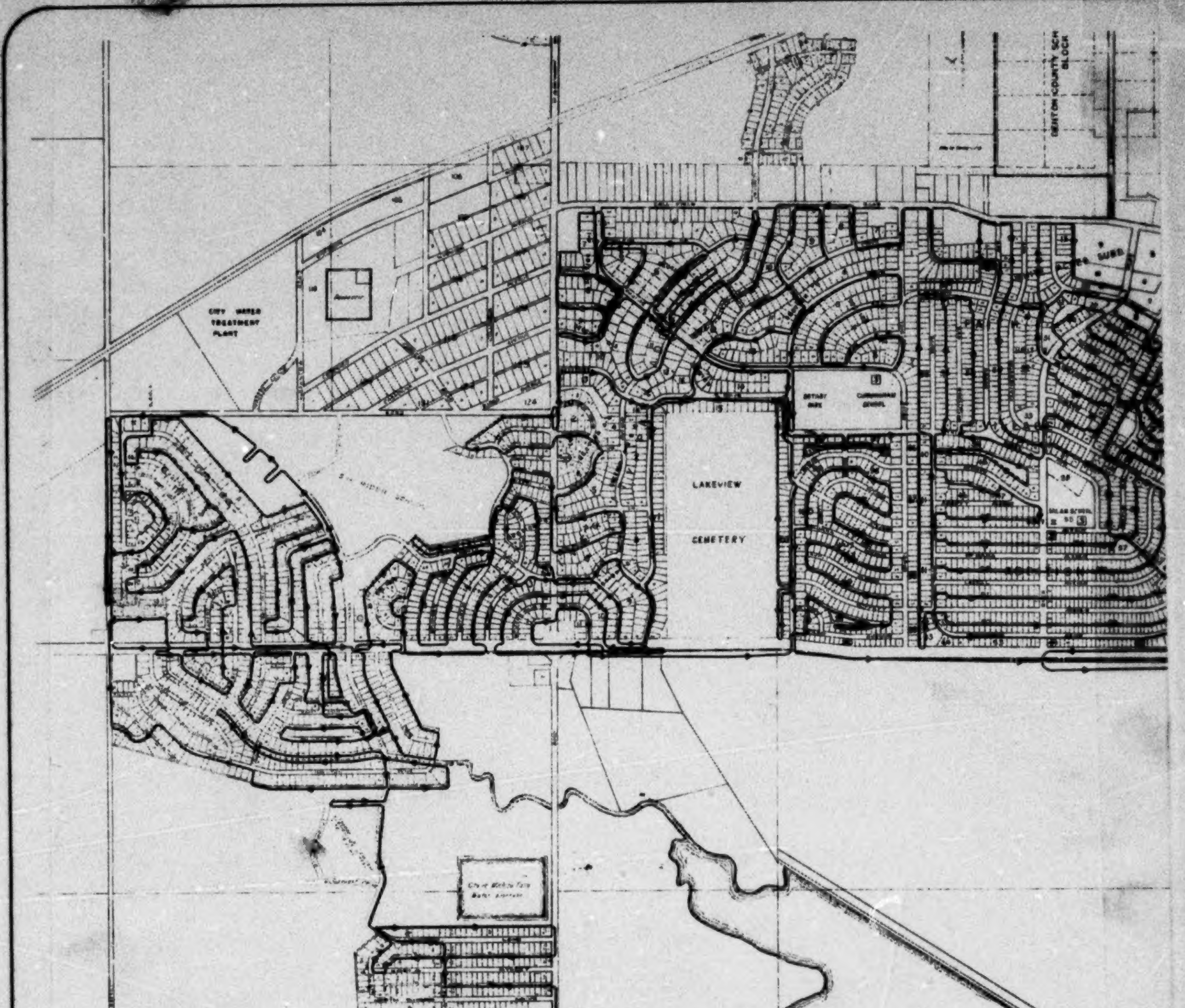
DENTON COUNTY SCH BLOCK
CITY WATER TREATMENT PLANT
ROTARY PARK
CUNNINGHAM SCHOOL
LAKEVIEW
CEMETERY
BEGIN
COUNTY
COUNTY
L A K E W I C H I T

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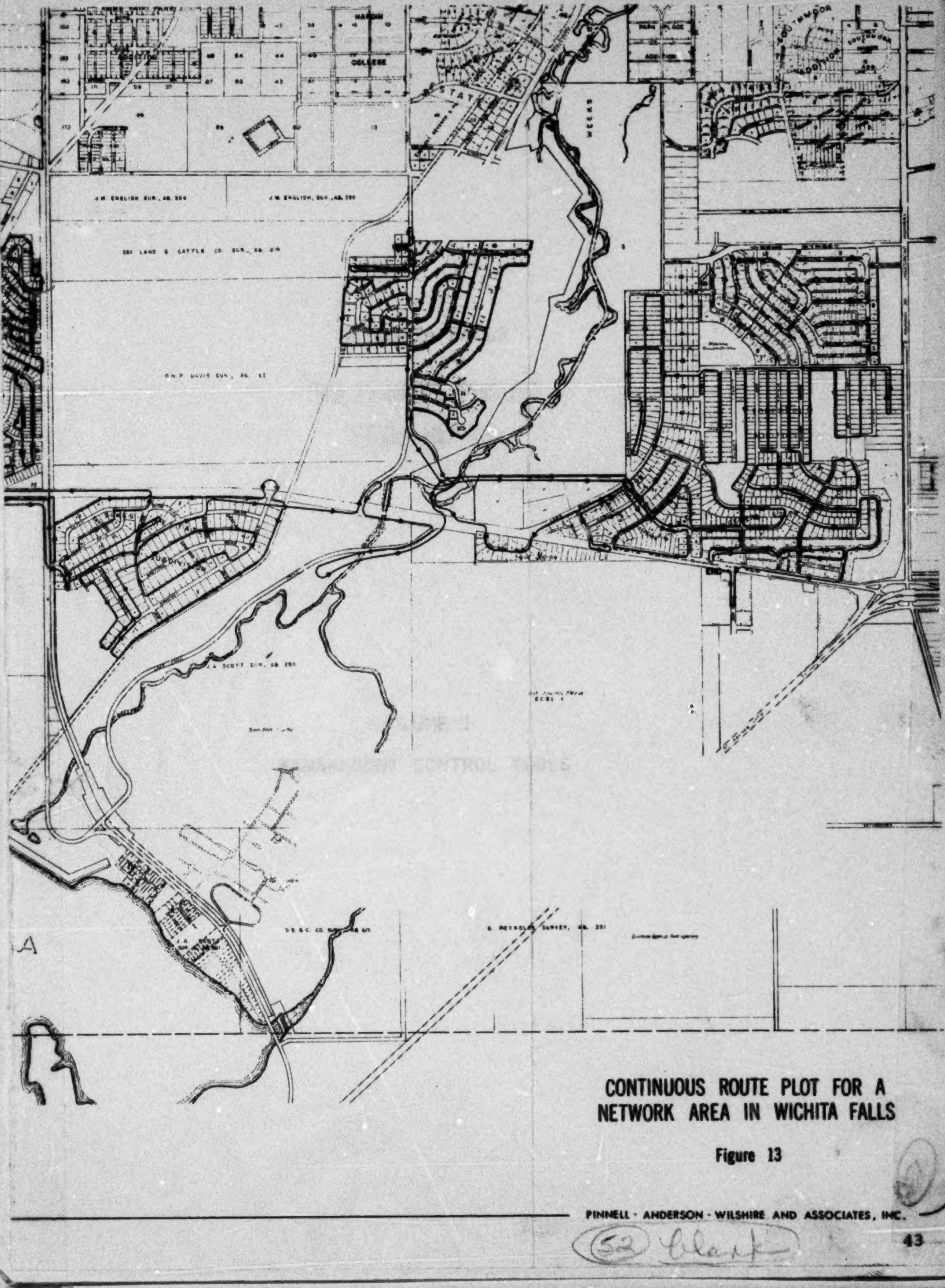

CONTINUOUS ROUTE PLOT FOR A NETWORK AREA IN WICHITA FALLS

Figure 13

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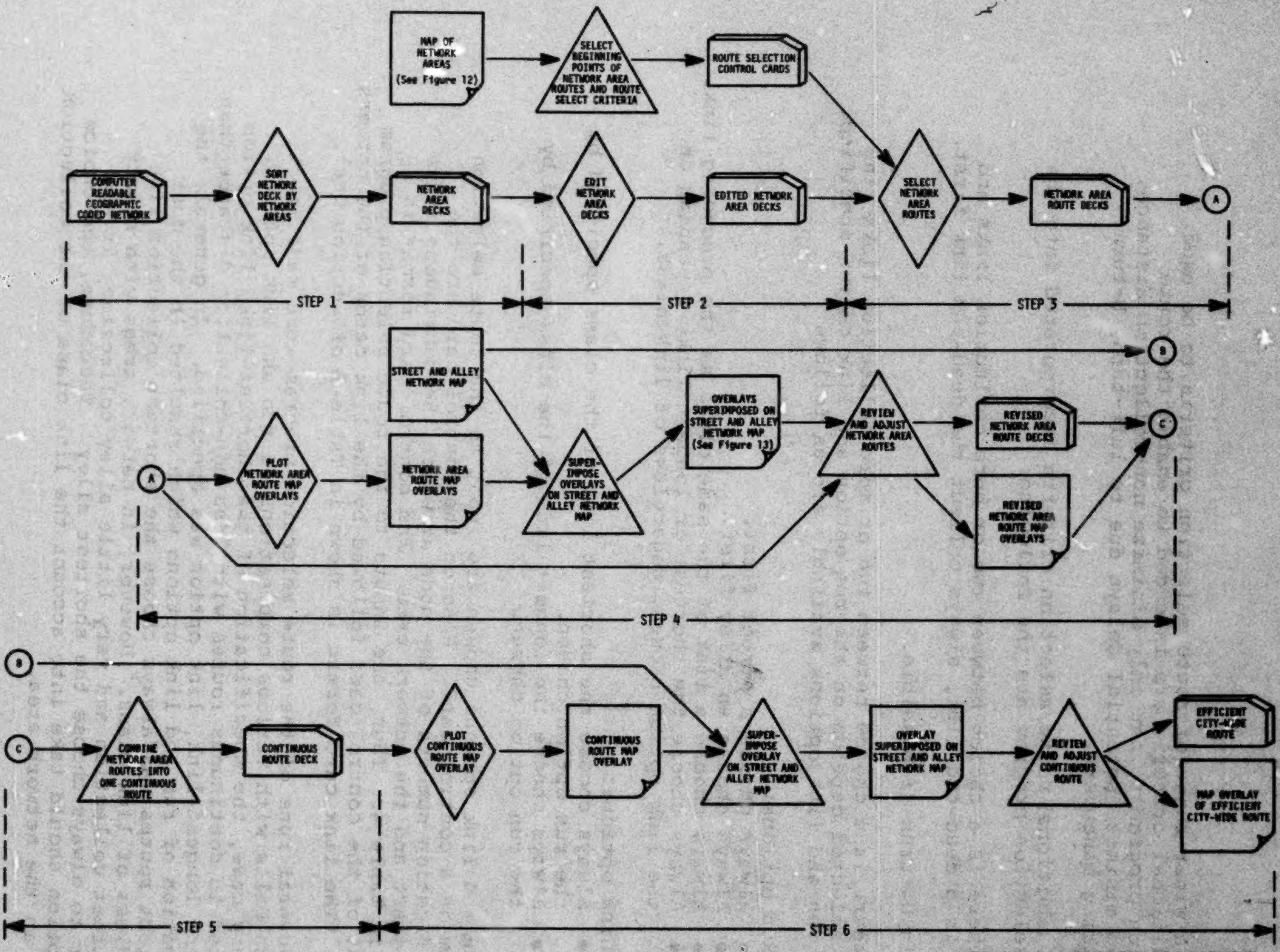
COMPUTER READABLE GEOGRAPHIC CODED NETWORK
SORT NETWORK DECK BY NETWORK AREAS
NETWORK AREA DECKS
MAP OF NETWORK AREAS (See Figure 12)
SELECT BEGINNING POINTS OF NETWORK AREA ROUTES AND ROUTE SELECT CRITERIA
ROUTE SELECTION CONTROL CARDS
EDIT NETWORK AREA DECKS
EDITED NETWORK AREA DECKS
SELECT NETWORK AREA ROUTES
NETWORK AREA ROUTE DECKS
A
STEP 1
STEP 2
STEP 3
STREET AND ALLEY NETWORK MAP
B
A
PLOT NETWORK AREA ROUTE MAP OVERLAYS
NETWORK AREA ROUTE MAP OVERLAYS
SUPER-IMPOSE OVERLAYS ON STREET AND ALLEY NETWORK MAP
OVERLAYS SUPERIMPOSED ON STREET AND ALLEY NETWORK MAP (See Figure 13)
REVIEW AND ADJUST NETWORK AREA ROUTES
REVISED NETWORK AREA ROUTE DECKS
REVISED NETWORK AREA ROUTE MAP OVERLAYS
C
STEP 4
B
C
COMBINE NETWORK AREA ROUTES INTO ONE CONTINUOUS ROUTE
CONTINUOUS ROUTE DECK
PLOT CONTINUOUS ROUTE MAP OVERLAY
CONTINUOUS ROUTE MAP OVERLAY
SUPER-IMPOSE OVERLAY ON STREET AND ALLEY NETWORK MAP
OVERLAY SUPERIMPOSED ON STREET AND ALLEY NETWORK MAP
REVIEW AND ADJUST CONTINUOUS ROUTE
EFFICIENT CITY-WIDE ROUTE
MAP OVERLAY OF EFFICIENT CITY-WIDE ROUTE
STEP 5
STEP 6

ROUTE SELECTION PROCEDURE

Figure 14

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permit a wider range of route selection criteria to be used. The additional criteria are intended to enable the route selection program to not only minimize non-collection distance, but also minimize potential delays due to left-turn, U-turn, and backing maneuvers.

The additional route selection criteria incorporated into the route selection program are the following:

- If there is a choice between two or more collection links and one is a dead-end link, always collect the dead-end link first.
- Avoid U-turns if possible.
- If there is a choice between two or more collection links, the one selected depends on the run option and link option specified. The run and link options available are as follows:
    - Run options:
        - Always choose a street first.
        - Always choose an alley first.
        - Always choose a link of the same class as the preceding link.
        - Always choose the shortest or longest link, depending on the link option chosen, regardless of link class.
    - Link options:
        - Always choose the shortest link of the class specified by the run option chosen.
        - Always choose the longest link of the class specified by the run option chosen.

The run and link options chosen are input to the route selection program on a control card. Also on the control card are the identification numbers of the node at which the continuous route is to start and the network area. The control card format is shown in Table 4. Thus, the inputs to the route selection program consist of the control card followed by the link cards of the network area. (The link card format is shown in Table 1 of Section One).

Several runs of the route selection program were made in Wichita Falls with various combinations of run and link options. In every case, the specification of the shortest-link, link option resulted in continuous routes with less non-collection distance than when the longest-link, link option was specified. In general, the combination of run and link options which resulted in the most efficient routes was "always choose the shortest collection link regardless of link class." However, in network areas with nearly all street collection and very little alley collection, it was better to always choose the shortest alley. Therefore, the choice run option should take into account the link class of the collection links in the network area.

TABLE 4. INPUT DATA CONTROL CARD FORMAT FOR ROUTE SELECTION PROGRAM

CARD COLS.	DATA
1-5	Starting node ID number
8	Run option (S - always choose a street first; A - always choose an alley first; L - always choose a link of the same class as the preceding link; blank - always choose the shortest or longest link, depending on the link option chosen, regardless of link class)
10	Link option (S - always choose the shortest link of the class specified by the run option chosen; L - always choose the longest link of the class specified by the run option chosen)
12-14	Network area ID number
16	Punch option (P - printed and punched output of continuous route description; blank - printed output of continuous route description)

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ROUTE SELECTION DEMONSTRATION

The route selection procedure was tested on a collection area in Odessa, Texas, and was used to establish a continuous collection route for the entire city of Wichita Falls. The results of these applications of the route selection procedure are briefly discussed in the remainder of this chapter.

Odessa

The collection area in Odessa used to test the automated network coding techniques was also used to test the route selection procedure. This area, which is shown in Figure 4 of Section One, contained 853 nodes and 2785 links, and it encompassed about 1/6 of the city. Since the area is not divided by any man-made or natural barriers, it was processed as a single network area. The link cards were prepared using the automated network coding techniques.

Two runs of the route selection program were made. The same beginning point was used in both runs. However, in the first run (Run 1), the run and link options used were to "always choose the longest link regardless of link class." And in the second run (Run 2), the run and link options used were to "always choose the shortest link regardless of link class."

A comparison of the mileage of the two routes selected and the existing route in the area is shown in Table 5. The computer selected routes contain about 10 miles less non-collection distance than the existing route contains. And, the non-collection distance of the route selected in Run 2 is about 1.5 miles less than that of the route selection in Run 1. Thus, the shortest-link, link option yielded a more efficient route than did the longest-link, link option, which agrees with results of other runs in Wichita Falls discussed in another report.(2)

Wichita Falls

As discussed previously, the collection network in Wichita Falls was divided into 13 network areas shown in Figure 12. The route selection procedure was used to find an efficient continuous route for the entire city.

A mileage comparison between the continuous route selected and the 40 existing routes, which were determined manually, is shown in Table 6. The continuous route has over 100 miles less non-collection distance than do the existing routes. Solid waste is collected twice a week in Wichita Falls. Therefore, implementation of the continuous route selected would result in 200 miles per week less travel on collection routes by collection crews.

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TABLE 5. ODESSA COLLECTION ROUTE MILEAGE COMPARISON

Route	Collection Distance		Non-Collection Distance		Total Distance
	Miles	Percent	Miles	Percent	Miles
Existing	28.2	51	26.8	49	55.0
Run 1	28.2	62	17.5	38	45.7
Run	28.2	64	16.1	36	44.3

TABLE 6. WICHITA FALLS COLLECTION ROUTE MILEAGE COMPARISON

Route	Collection Distance		Non-Collection Distance		Total Distance
	Miles	Percent	Miles	Percent	Miles
Existing	287.5	54	240.8	46	528.3
Continuous	287.5	68	138.3	32	425.8

In Wichita Falls, the average fuel consumption rate and the average non-collection speed on collection routes have been found to be equal to 5 gallons per mile and 12.5 miles per hour, respectively. Therefore, the 200 miles per week reduction translates into a savings of 40 gallons of fuel per week and 16 collection-crew hours per week. The 16 collection-crew hours is equivalent to 2 collection-crew days or one collection route. Also, additional collection-crew time savings would probably be realized because it is likely that the continuous route selected requires fewer left-turn, U-turn, and backing maneuvers than do the existing routes.

CONCLUSIONS

The route selection procedure described in this chapter has consistently selected continuous collection routes that contain considerably less non-collection distance than do existing, manually selected routes. Also, the routes it has selected contain a minimum of delay causing maneuvers such as left-turns, U-turns, and backing. However, this route selection procedure does not guarantee the selection of the most efficient route. But instead, it provides a rational, economical method of designing collection routes that will be as efficient, and usually more efficient, than those that are designed manually.

In addition, the continuous route provided by this procedure facilitates the utilization of automated techniques for route evaluation or balancing. Thus, equitable collection route assignments can be readily determined to account for seasonal variations in workload and changes in collection systems. Also, the route deck of the continuous route can easily be adjusted to incorporate changes in the collection network and consequently enable timely evaluation of collection route assignments.

The automated techniques for route evaluation developed in this study are discussed in the next chapter.

ROUTE EVALUATION

OBJECTIVE

The objective of route evaluation is optimum utilization of collection resources. Route evaluation is intended to equitably distribute the solid waste collection workload among collection crews. Thus, the route evaluation procedure is used to divide the efficient continuous collection route determined by route selection into efficient, well-balanced colleotion route assignments.

ROUTE DATA REQUIREMENTS

The route evaluation procedure requires a computer readable description of a continuous collection route. The required route data is a deck of link cards that describes in sequence each link of the continuous route. The following data are required for each link:

- A node ID and X-Y coordinates
- B node ID and X-Y coordinates
- Link distance
- Number of residential units
- Average floor area per residential unit
- Average number of persons per residential unit
- Average income per residential unit
- Number of carry-outs
- Carry-out class (based on distance from curb)
- Sequence number

These data are provided as output from the route selection procedure presented in Chapter II. However, if the route data deck is prepared by other means, it should be edited to ensure that the route is continuous and that the data fields are complete and correct. The link card format for these data is the same as that shown in Table 1 of Section One , with the link sequence number in card columns 76-80.

PROCEDURE

The route evaluation procedure, which divides a continuous collection route into well-balanced collection route assignments, consists of the following steps:

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(1) The values of the collection system parameters and environmental factors are determined. These data define the collection conditions under which the continuous route is to be evaluated. The collection system parameters to be specified are the following:

- Collection vehicle capacity
- Length of collection day
- Minimum time left in collection day to allow collection vehicle to begin to collect another load
- Average collection vehicle travel time to and from disposal site between loads; or in the case of a container-train system, average waiting and dumping time of train between loads

And, the environmental factors to be specified are the following:

- Month of the year
- Number of days since the last collection
- Weather coefficient which indicates the degree to which the collection operation is hampered by adverse weather conditions

Thus, the route evaluation procedure can be applied to determine equitable collection route assignments for a wide variety of collection conditions.

(2) The route data deck and the collection conditions are input to the route evaluation program. The route evaluation program determines the number of collection route assignments in the continuous collection route. And, for each assignment, it computes the amount of solid waste to be collected, the time required, and the points on the continuous route at which the assignment begins and ends. In addition, the route evaluation program summarizes the link data descriptions of the links contained within each assignment.

(3) The points at which each collection route assignment begins and ends are plotted on the map overlay of the continuous collection route prepared in the route selection procedure described in Chapter II.

(4) The route assignments plot and the route evaluation program output are reviewed to determine the rationality of the route assignments. It may be desirable to make minor adjustments to the beginning and ending points of some route assignments in order to improve the route assignments as follows:

- Eliminate non-collection links at the beginning and end of route assignments
- Increase compactness of route assignments
- Avoid crossing network barriers within route assignments
- Refine workload balance between adjacent route assignments

The adjusted route assignments are plotted on a map overlay of the continuous route. However, if major adjustments are indicated, the impact of system parameters on route assignments should be considered. In other words, changes in the collection system may be necessary to achieve well-balanced route assignments.

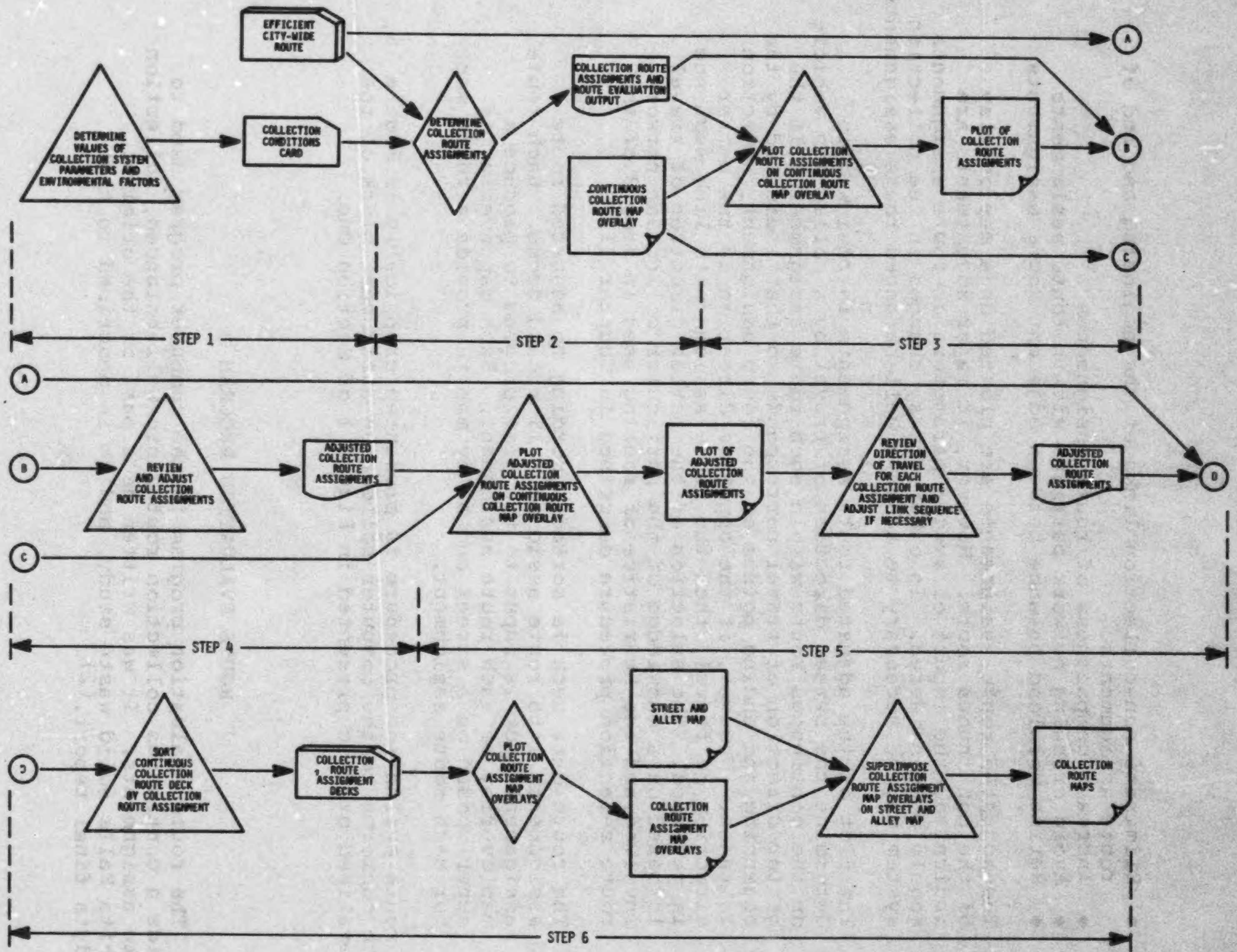
(5) The plot of the adjusted route assignments is reviewed to determine the better direction of travel by a collection vehicle on the continuous route within each route assignment. If the better direction of travel corresponds to that indicated by the beginning and ending points of the route assignment, no action is taken. However, if the opposite direction is the better direction of travel, then the route assignment's link sequence is reversed. The selection of the better direction of travel is based on a knowledge of the particular collection network involved and the heuristics of routing used in step 3 of the route selection procedure described in Chapter II.

(6) The route data deck is sorted according to adjusted route assignments into route assignment link card decks. Each route assignment deck is input to the plot program to produce a map overlay of each route assignment. Each map overlay is superimposed on a street and alley map to provide a route map for each route assignment.

The route evaluation procedure is presented graphically in Figure 15, which conforms to the computer collection assignment block of the generalized graphic presented in Figure 1 of Section One.

ROUTE EVALUATION PROGRAM

The route evaluation program is the computer program used to divide a continuous collection route into well-balanced, collection route assignments. It was written as a part of the original Wichita Falls solid waste study, and it is described in that study's final report.(2)


DETERMINE VALUES OF COLLECTION SYSTEM PARAMETERS AND ENVIRONMENTAL FACTORS
EFFICIENT CITY-WIDE ROUTE
COLLECTION CONDITIONS CARD
DETERMINE COLLECTION ROUTE ASSIGNMENTS
COLLECTION ROUTE ASSIGNMENTS AND ROUTE EVALUATION OUTPUT
CONTINUOUS COLLECTION ROUTE MAP OVERLAY
PLOT COLLECTION ROUTE ASSIGNMENTS ON CONTINUOUS COLLECTION ROUTE MAP OVERLAY
PLOT OF COLLECTION ROUTE ASSIGNMENTS
A
B
C
STEP 1
STEP 2
STEP 3
A
B
C
REVIEW AND ADJUST COLLECTION ROUTE ASSIGNMENTS
ADJUSTED COLLECTION ROUTE ASSIGNMENTS
PLOT ADJUSTED COLLECTION ROUTE ASSIGNMENTS ON CONTINUOUS COLLECTION ROUTE MAP OVERLAY
PLOT OF ADJUSTED COLLECTION ROUTE ASSIGNMENTS
REVIEW DIRECTION OF TRAVEL FOR EACH COLLECTION ROUTE ASSIGNMENT AND ADJUST LINK SEQUENCE IF NECESSARY
ADJUSTED COLLECTION ROUTE ASSIGNMENTS
D
STEP 4
STEP 5
D
SORT CONTINUOUS COLLECTION ROUTE DECK BY COLLECTION ROUTE ASSIGNMENT
COLLECTION ROUTE ASSIGNMENT DECKS
PLOT COLLECTION ROUTE ASSIGNMENT MAP OVERLAYS
STREET AND ALLEY MAP
COLLECTION ROUTE ASSIGNMENT MAP OVERLAYS
SUPERIMPOSE COLLECTION ROUTE ASSIGNMENT MAP OVERLAYS ON STREET AND ALLEY MAP
COLLECTION ROUTE MAPS
STEP 6

ROUTE EVALUATION PROCEDURE

Figure 15

Inputs

Inputs to the route evaluation program consist of the following:

- Run identification card (see Table 7)
- Collection conditions card (see Table 8)
- Continuous route data cards (see Table 1)

The formats of these cards are presented in the tables referenced above.

The original route evaluation program did not consider the following factors in predicting the workload along a collection route:

- Number of persons per residential unit
- Income per residential unit
- Number and class of carry-outs

However, the results of subsequent studies in Wichita Falls have indicated that:

- The amount of solid waste generated along a route is affected by the number of persons and average income of the residential units on the route.
- The time required to complete a route is affected by the number and class of carry-outs on the route.

Therefore, the original route evaluation program has been modified to accept a more detailed description of the collection route which includes these factors.

Outputs

Outputs of the route evaluation program consists of a series of load, collection vehicle, and route summaries. The original route evaluation program has been modified to provide summaries which contain the following information for each load, collection vehicle or route assignment, and the entire continuous route:

- Identification of beginning and ending points
- Amount of solid waste collected
- Total time required
- Total collection and non-collection distances
- Total number of residential units served
- Average floor area, average number of persons, and average income per residential unit served
- Total number of each class of carry-out served

TABLE 7. RUN IDENTIFICATION CARD FORMAT

CARD COLS.	DATA
1-40	City
41-44	Run ID number
45-64	Date

TABLE 8. COLLECTION CONDITIONS CARD FORMAT

CARD COLS.	DATA
1-6	Collection vehicle capacity (pounds)
7-8	Month of year (1=Jan.; 2=Feb., etc.)
9-10	Number of days since the last collection (1=3 days, 2=4 days)
11-14	Weather coefficient (1.00 indicates dry weather conditions. Other weather conditions can be defined and specified as less than 1.00 to provide a range of conditions from extremely wet to dry)
15-18	Length of collection day (hours)
19-22	Average travel time to and from disposal site plus dump time between loads; or average waiting and dumping time between loads (hours)
23-26	Minimum allowable time left in collection day to start another load (hours)

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Examples of these summaries are shown in Figures 16, 17, and 18.

The original route evaluation program has also been revised to output a summary data card for each route assignment which contains the same information that it prints in the route's collection vehicle, or route assignment, summary. These cards can be input to a computer program that prints these data in the summary report format shown in Figure 19. This summary report facilitates review of the route assignments.

Applications

The most obvious use of the route evaluation program is to determine equitable route assignments for a continuous collection route under a given set of collection conditions. However, because the route evaluation program accounts for the effects of changes in values of collection system parameters and environmental factors, it also has some other applications.

The route evaluation program considers the effects of changes in the following environmental factors:

- Month of the year
- Number of days since last collection
- Weather conditions

Therefore, for a given continuous collection route and collection system, the route evaluation program can be used to develop an optimal route assignment strategy for seasonal or daily variations in collection workload due to these factors.

In a similar manner, the route evaluation program can be used to determine the effects of collection system parameters on route assignments. Consequently, for a given continuous route and set of environmental factor values, the route evaluation program can provide a basis for selecting the best collection system parameter values (e.g., optimum collection vehicle capacity or optimum length of collection day).

The following collection vehicle performance characteristics are used in the route evaluation program to compute the time required to complete a collection route assignment:

- Non-collection speeds
- Collection times per residential unit
- Collection times per carry-out for each carry-out class

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```
LOAD NO.  1, TRAIN NO. 11
*************************
START COLLECTION NODE NO. 41680 (SEQ. NO. 19530)
END COLLECTION NODE NO. 26243 (SEQ. NO. 20360)
AMOUNT OF SOLID WASTE COLLECTED . . . . . . . . . . . . . 3613 LBS.
COLLECTION TIME . . . . . . . . . . . . . . . . . . . . . 1.36 HRS
WAITING AND DUMPING TIME  . . . . . . . . . . . . . . . . 0.25 HRS
COLLECTION DISTANCE . . . . . . . . . . . . . . . . . . . 2.79 MILES
NON-COLLECTION DISTANCE . . . . . . . . . . . . . . . . . 2.55 MILES
NO. OF RESIDENTIAL UNITS SERVED . . . . . . . . . . . . . 143
AVG. FLOOR AREA PER RESID. UNIT SERVED. . . . . . . . . . 949 SQ.FT.
AVG. NO. OF PEOPLE PER RESID. UNIT SERVED . . . . . . . . 2.3
AVG. INCOME PER RESID. UNIT SERVED  . . . . . . . . . . . $5435.
NO. OF TYPE-ONE CARRY OUTS  . . . . . . . . . . . . . . . 2
NO. OF TYPE-TWO CARRY OUTS  . . . . . . . . . . . . . . . 0
NO. OF TYPE-THREE CARRY OUTS  . . . . . . . . . . . . . . 0
TOTAL CUMULATIVE TIME . . . . . . . . . . . . . . . . . . 1.61
COLLECTION TERMINATED ON TRAIN CAPACITY

LOAD NO. 2, TRAIN NO. 11
************************
START COLLECTION NODE NO. 26243 (SEQ. NO. 20370)
END COLLECTION NODE NO. 25433 (SEQ. NO. 21270)
AMOUNT OF SOLID WASTE COLLECTED . . . . . . . . . . . . . 3619 LBS
COLLECTION TIME . . . . . . . . . . . . . . . . . . . . . 1.45 HRS
WAITING AND DUMPING TIME  . . . . . . . . . . . . . . . . 0.25 HRS
COLLECTION DISTANCE . . . . . . . . . . . . . . . . . . . 2.05 MILES
NON-COLLECTION DISTANCE . . . . . . . . . . . . . . . . . 2.34 MILES
NO. OF RESIDENTIAL UNITS SERVED . . . . . . . . . . . . . 159
AVG. FLOOR AREA PER RESID. UNIT SERVED  . . . . . . . . . 944 SQ.FT.
AVG. NO. OF PEOPLE PER RESID. UNIT SERVED . . . . . . . . 2.1
AVG. INCOME PER RESID. UNIT SERVED  . . . . . . . . . . . $5192.
NO. OF TYPE-ONE CARRY OUTS  . . . . . . . . . . . . . . . 0
NO. OF TYPE-TWO CARRY OUTS  . . . . . . . . . . . . . . . 4
NO. OF TYPE-THREE CARRY OUTS  . . . . . . . . . . . . . . 0
TOTAL CUMULATIVE TIME . . . . . . . . . . . . . . . . . . 3.31 HRS
COLLECTION TERMINATED ON TRAIN CAPACITY
```

ROUTE EVALUATION PROGRAM OUTPUT - LOAD SUMMARY

Figure 16

```
                    SUMMARY - TRAIN NO. 11
                    **********************

START COLLECTION NODE NO. 41680 (SEQ. NO. 19530)

END COLLECTION NODE 37922 (SEQ. 22460)

TOTAL AMOUNT OF SOLID WASTE COLLECTED . . . . . . . . . . . . . 20509 LBS

TOTAL CUMULATIVE TIME . . . . . . . . . . . . . . . . . . . . . 8.10 HRS

TOTAL COLLECTION DISTANCE . . . . . . . . . . . . . . . . . . . 9.54 MILES

TOTAL NON-COLLECTION DISTANCE . . . . . . . . . . . . . . . . . 7.12 MILES

TOTAL NO. OF RESIDENTIAL UNITS SERVED . . . . . . . . . . . . . 807

AVG. FLOOR AREA PER RESID. UNIT SERVED  . . . . . . . . . . . . 1193 SQ.FT.

AVG. NO. OF PEOPLE PER RESID. UNIT SERVED . . . . . . . . . . . 1.9

AVG. INCOME PER RESID. UNIT SERVED  . . . . . . . . . . . . . . $5640.

TOTAL NO. OF TYPE-ONE CARRY OUTS  . . . . . . . . . . . . . . . 2

TOTAL NO. OF TYPE-TWO CARRY OUTS  . . . . . . . . . . . . . . . 7

TOTAL NO. OF TYPE-THREE CARRY OUTS  . . . . . . . . . . . . . . 0
```

ROUTE EVALUATION PROGRAM OUTPUT - COLLECTION VEHICLE SUMMARY

Figure 17

```
                    ROUTE SUMMARY
                    *************

START COLLECTION NODE NO. 22918 (SEQ. NO.      0)

END COLLECTION NODE NO. 15649 (SEQ. NO. 58630)

TOTAL AMOUNT OF SOLID WASTE COLLECTED . . . . . . . . . . . . . 860930 LBS

TOTAL CUMULATIVE TIME . . . . . . . . . . . . . . . . . . . . . 316.07 HRS

TOTAL COLLECTION DISTANCE . . . . . . . . . . . . . . . . . . . 287.51 MILES

TOTAL NON-COLLECTION DISTANCE . . . . . . . . . . . . . . . . . 138.31 MILES

TOTAL NO. OF RESIDENTIAL UNITS SERVED . . . . . . . . . . . . . 28279

AVG. FLOOR AREA PER RESID. UNIT SERVED  . . . . . . . . . . . . 1178 SQ.FT.

AVG. NO. OF PEOPLE PER RESID. UNIT SERVED . . . . . . . . . . . 2.5

AVG. INCOME PER RESID. UNIT SERVED  . . . . . . . . . . . . . . $9579.

TOTAL NO. OF TYPE-ONE CARRY OUTS  . . . . . . . . . . . . . . . 136

TOTAL NO. OF TYPE-TWO CARRY OUTS  . . . . . . . . . . . . . . . 744

TOTAL NO. OF TYPE-THREE CARRY OUTS  . . . . . . . . . . . . . . 696

NO. OF TRAINS REQUIRED  . . . . . . . . . . . . . . . . . . . . 40
```

ROUTE EVALUATION PROGRAM OUTPUT - ROUTE SUMMARY

Figure 18

```
        START  START   END    END                    COL.   N-C          AVG.   AVG.    AVG.
TRAIN   NODE   SEQ.    NODE   SEQ.    SWC    TIME    DIST   DIST   NO.   FA/RU  POP    INC/RU   NO.   NO.   NO.    NO.
 NO.    NO.    NO.     NO.    NO.    (LBS)   (HRS)   (MI)   (MI)   RU    (FT2)  /RU     ($)     CO1   CO2   CO3   LOADS
*****  *****  *****   ****   ****   *****   *****   ****   ****   **    *****  ****   ******   ***   ***   ***   *****

  1    22918      0   20224   1650  19416    7.47    6.63   2.98  797     924   2.3     6424.    0     1     0      5
  2    20224   1660   22712   3090  23221    8.11   10.66   5.04  792     973   2.7     6913.    0     0     0      6
  3    22712   3100   21043   4640  28262    7.45    7.13   5.06  676    1076   3.9     8410.    0    11     0      7
  4    21043   4650   28808   6180  27305    7.41    7.49   5.62  689    1052   3.7     8148.    0     0     0      7
  5    28808   6190   26953   8420  22596    7.55   10.24   7.04  696     998   3.0     6807.    0     0     0      6
  6    26953   8430   26323  10980  18524    8.11    8.00   5.16  857     751   2.3     5080.    0     0     0      5
  7    26323  10990   22823  13230  18925    7.82    8.03   5.15  812     785   2.4     5068     0     0     0      5
  8    22823  13240   33216  15500  15390    7.77    7.97   5.22  816     861   1.8     6067.    0    12     0      4
  9    33216  15510   20859  17990  18659    8.26   10.28   5.97  839     841   2.2     6434.    0     2     0      5
 10    20859  18000   41680  19520  24271    7.87    9.11   4.10  781     975   2.9     7879.    0     2     0      6
 11    41680  19530   37922  22460  20509    8.10    9.54   7.12  807    1193   1.9     5640.    2     7     0      5
 12    37922  22470   33248  23570  22812    8.18    4.59   1.41  896    1169   1.9     7260.    0     5     0      6
 13    33248  23580   24789  24590  22244    8.29    5.01   1.44  917    1066   2.0     7832.    0     0     0      6
 14    24789  24600   28549  26190  18994    7.42    5.40   2.92  786    1076   2.0     7112.    0     5     2      5
 15    28549  26200   37672  26880  22839    8.20    4.15   0.64  922    1079   2.0     8197.    0     0     0      6
 16    37672  26890   43915  27780  23217    7.78    4.77   1.17  845    1194   2.1    10260.    0     2     0      6
 17    43915  27790   28590  29670  21434    8.21    8.73   4.28  821    1150   2.0     8865.    8    25     0      5
 18    28590  29680   43350  31140  19887    8.15    6.14   2.16  807    1094   2.0     7255.    2    25    10      5
 19    43350  31150   46825  32650  18971    8.24    7.52   4.21  610    1278   2.4    19161.    2    80    23      5
 20    46825  32660   35131  34210  22682    8.13    9.34   4.84  602    2087   2.3    17360.    8    60    17      6
 21    35131  34220   39258  35950  22794    8.32    6.43   3.26  883    1034   2.2    10117.    0     1     0      6
 22    39258  35960   40006  37300  28263    7.60    8.46   2.46  729    1545   2.7    11200.    0     0     0      7
 23    40006  37310   35355  39450  26343    8.27   10.46   5.64  773    1445   2.6    10987.    0     1     0      7
 24    35355  39460   32620  40350  19035    8.54    5.48   2.43  471    1858   2.4    17181.   17    63    76      5
 25    32620  40360   31032  40820  10605    8.55    4.00   1.18  226    2348   2.2    21689.   12    31   161      3
 26    31032  40830   31015  41400   9912    8.28    4.47   1.30  196    2574   2.2    21123.   11    18   163      3
 27    31015  41410   40402  42160  14720    8.28    4.18   0.67  484    1395   2.1    10200.   17    49    85      4
 28    40402  42170   37719  43510  17895    8.28    6.02   1.85  751     997   2.1     8352.   46    60    11      5
 29    37719  43520   45710  45450  19042    7.92    7.58   3.41  842     821   2.3     8040.    9     3     0      5
 30    45710  45460   17983  47080  22812    8.39    8.86   3.36  805     939   2.7     9501.    0    29     0      6
 31    17983  47090   12071  48560  20287    7.47    7.50   4.36  541    1491   2.7    13238.    2    45    29      5
 32    12071  48570   11163  50410  23456    7.35    8.63   5.99  700    1279   2.6    10679.    0     0     0      6
 33    11163  50420   11289  51360  25839    8.47    7.27   1.57  619    1636   2.9    13561.    0   108     6      7
 34    11289  51370   17125  52200  21058    7.31    7.18   2.55  436    2216   2.6    17178.    0    66    41      5
 35    17125  52210   10483  53290  27507    8.29    8.74   3.40  810    1278   2.7    11765.    0     2     1      7
 36    10483  53300   10287  54200  27546    7.97    6.71   1.61  812    1079   3.0    10248.    0     0     0      7
 37    10287  54210   14405  55580  20432    7.39    6.97   3.38  634    1166   2.7    10572.    0    11    25      5
 38    14405  55590   13173  56650  24064    8.19    6.46   2.88  605    1287   3.3    12543.    0    20    46      6
 39    13173  56660   15876  58070  32321    8.21    7.78   4.05  777    1294   3.5    11785.    0     0     0      8
 40    15876  58080   15649  58630  16841    4.49    3.61   1.42  417    1062   3.8     9056.    0     0     0      5

TOTAL TIME = 316.07 HRS

TOTAL NO. OF LOADS = 223
```

ROUTE EVALUATION PROGRAM OUTPUT - SUMMARY REPORT

Figure 19

The values used for these variables in the route evaluation program are for the container-train system in Wichita Falls. However, the route evaluation program could easily be modified to include values of these performance characteristics for other types of collection systems. If such a revision was made, the route evaluation program could determine collection route assignments for the various types of collection systems. And thus, it could be used to provide a basis for selecting the best type of collection system for a given continuous collection route and set of environmental conditions.

ROUTE EVALUATION DEMONSTRATION

The route evaluation procedure was demonstrated using the continuous collection route selected for Wichita Falls. It was used to assign balanced collection routes to the trains of the container-train system currently being used in Wichita Falls. Also, the route evaluation program was used to illustrate the impact on collection workload of various changes in the collection conditions in Wichita Falls.

Route Assignments

The residential solid waste collection system in Wichita Falls is a container-train system. It is composed of 20 trains and 5 container transfer vehicles which are organized into 5 convoys. Each convoy consists of a container transfer vehicle assigned to 4 trains. The trains collect the solid waste from the residential units. And, the container transfer vehicle dumps the trains on their routes when they become full and hauls the solid waste to the disposal site.

In Wichita Falls, solid waste is collected on a residential collection route twice a week: either on Monday and Thursday or Tuesday and Friday. Each train is assigned two collection routes: a Monday-Thursday route and a Tuesday-Friday route. Therefore, there are 40 collection route assignments in Wichita Falls.

The existing route assignments were made manually in 1968. At that time, an effort was made to balance the routes on the basis of a subjective estimate of workload. In addition, an attempt was made to lay out the routes of the convoys so as to minimize the travel of the container transfer vehicles. Consequently, the train routes of a convoy are usually overlapping.

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Today, the performance of the collection crews indicates that these routes are not balanced. Some crews complete their routes in 4 to 5 hours while other crews need 8 to 9 hours to complete theirs. Of course, because of changes that have occurred in the residential areas, the fact that the routes are not balanced is not surprising. New residential developments and population shifts have increased the amount of solid waste generated in some areas and reduced it in others. Also, the alley paving program conducted by Wichita Falls since 1968 has reduced the workload in areas where alleys have been paved. And other changes affecting workload could probably be cited.

Therefore, the route evaluation procedure was used to determine 40, well-balanced, collection route assignments for the 20 trains in Wichita Falls. The route deck for the continuous route selected for Wichita Falls was input to the route evaluation program together with the following collection conditions:

● Collection vehicle capacity	3600 pounds
● Length of collection day	8.0 hours
● Minimum allowable time left in collection day to start another load	45 minutes
● Average waiting and dumping time	15 minutes
● Month of the year	June
● Number of days since the last collection	4
● Weather coefficient	1.00

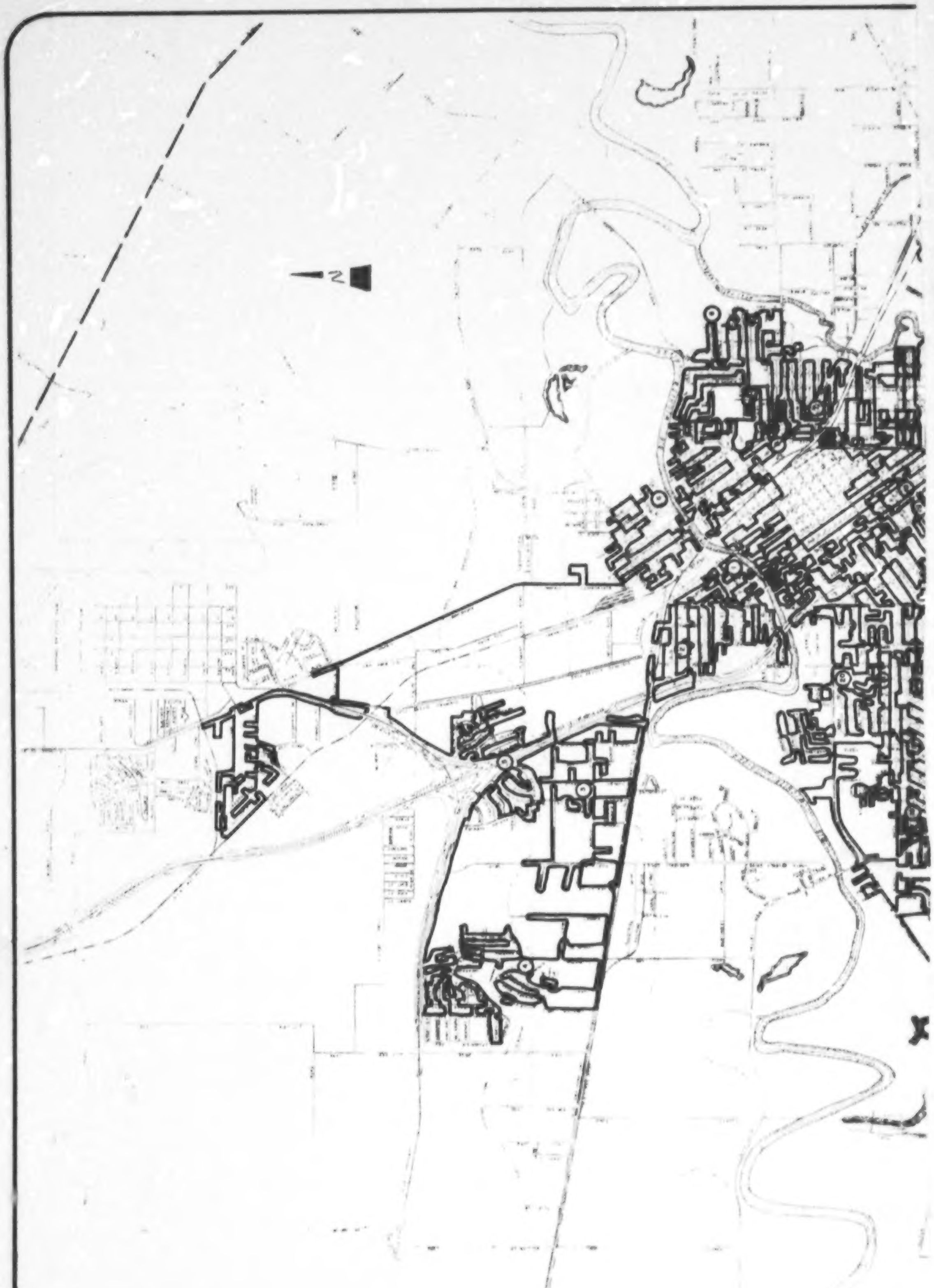
Four days since the last collection (Monday or Tuesday collection) in June is representative of heavy workload conditions in Wichita Falls.

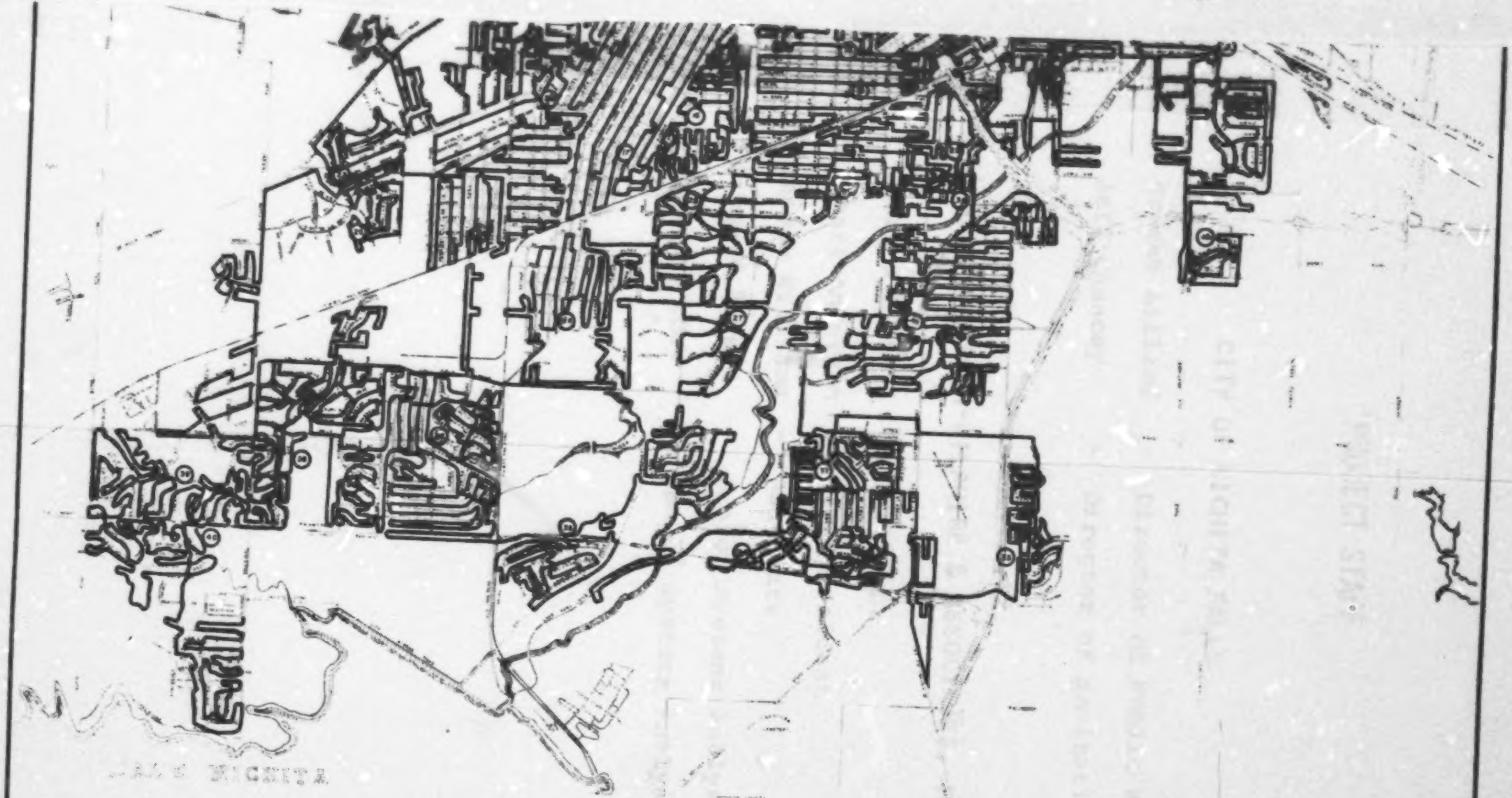
The collection route assignment summary report output by the route evaluation program is shown in Figure 19. It is evident that the route assignments indicated in this output are reasonably well-balanced. The time required by most of these assignments is about 8 hours. Minor manual adjustments to these assignments were made to eliminate unnecessary non-collection distance at the beginning and end of some assignments and to refine the workload balance between adjacent assignments. These adjusted route assignments are shown in Figure 20.

It should be noted that the route assignments are balanced on the basis of time required to complete them. And, the time required to complete them is not merely a function of the number of residential units served, but also depends on the following factors:

- Collection and non-collection distances traveled
- Number and class of carry-outs served

②


N



NOTE:
○ *denotes beginning point of route*

ROUTE ASSIGNMENTS FOR WICHITA FALLS
CONTAINER - TRAIN SYSTEM

Figure 20

(74) - blank

(73)

- Amount of solid waste collected, which is a function of characteristics of the residential units served such as floor area, number of persons, and income

The route evaluation procedure enables the effects of these factors to be considered.

Impact of Collection Conditions

The route evaluation program was used to compute the impact on the continuous collection route workload of various changes in collection conditions in Wichita Falls. The following is a summary of the changes considered and their workload impact:

- If carry-out service was eliminated, the total workload would be reduced by about 32 hours. For an 8-hour collection day, this 32 hours reduction is equivalent to 4 route assignments. Thus, the total number of 8-hour, collection route assignments required by the continuous collection route would be reduced from 40 to 36. And, for twice-a-week collection, this is equivalent to a reduction in number of trains required of 2, from 20 to 18 trains.

- If the workloads of the container transfer vehicles were better balanced and/or if the location of disposal sites were more convenient, it might be possible to reduce the average waiting and dumping time of trains between loads. If this time was reduced by 5 minutes, the total workload would be reduced by about 16 hours. For an 8-hour collection day, this 16 hours reduction is equivalent to 2 route assignments. And, for twice-a-week collection, this is equivalent to a reduction in number of trains required of 1.

- If the trains were replaced by packer trucks with a capacity of 14,000 pounds, the total workload would be reduced by nearly 48 hours. Thus, for an 8-hour collection day, twice-a-week collection, this means that it would take 17 packer trucks to replace the 20 trains. (To simulate packer truck travel to and from the disposal site between loads, an average time of 45 minutes was used for the average waiting and dumping time. Also, it was assumed that the collection rates of the packer trucks were the same as those of the trains. Therefore, the effect of capacity was the primary factor considered in this particular route evaluation.)

- If a 4-day work week was instituted in Wichita Falls, the length of the collection day would be 10 hours. And, for a 10-hour collection day, 32 collection route assignments would be required. Thus, for twice-a-week collection, a 4-day work week would enable a reduction of 4 trains, from 20 to 16.

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These examples illustrate the use of the route evaluation program as a means to evaluate the effects of certain changes in the solid waste collection system; and thus, serve as a solid waste collection management tool.

CONCLUSIONS

The route evaluation procedure described in this section is an effective means of balancing collection routes. In conjuntion with the automated network coding techniques and the route selection procedure, it forms an economical method for designing efficient, well-balanced collection routes.

SECTION TWO

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2. Systems Analysis Study Of The Container - Train Method Of Solid Waste Collection And Disposal: Route Selection And Evaluation, Final Report, Vol.II, Solid Waste Collection and Disposal Demonstration Project, Grant No. G06-EC-00135, June, 1971.

SECTION THREE

SOLID WASTE MANAGEMENT INFORMATION SYSTEM

CHAPTER I

INTRODUCTION

This section presents a description of the computer augmented management information system developed for the Solid Waste Division. The system provides accurate and timely information for use in effective allocation and control of the Division's resources.

An earlier information system, used in support of research as well as for management control, provided detailed weight information on each dump of each collection trailer. It also provided daily operational and maintenance cost information on each equipment piece and daily cost and performance information on each employee. The system functioned well in support of the research activities, but buried division managers in a mass of data.

The revised information system, described in this section, provides to the division administrators, on a daily and weekly basis, only those information elements which are most pertinent to the management control process.

An overview of the system components is followed by a description of system inputs and data files. The program logic is presented in narrative form followed by samples of the management reports produced by these programs. The final chapter presents guidelines and procedures for accomplishing the daily data collection on which the information system depends. This chapter can be detached and distributed as a users manual.

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SYSTEM COMPONENTS

The information system components and component relationships are depicted in Figure 21. The system is a two phase process.

During the file maintenance phase, source data cards are read and two reference data files are created or modified. The first file contains descriptive information on each collection vehicle. The second file contains the route description with one record for each link of each residential collection route. Fixed container and convoy routes are each represented by a single record.

The file maintenance programs are run to create the reference files when the system is initialized. These programs are also run as needed to modify data elements on the reference files. The outputs of the file maintenance programs are:

- The disk resident route description file
- The disk resident equipment roster file
- A listing of the equipment rosters, to be used as a reference document
- A listing of the route description, to be used as a reference document
- A listing of invalid input cards with associated diagnostic messages

The data collection/reporting phase programs, on a daily basis, read source data cards containing:

- City owned truck, weight and time data collected at the landfill
- Private vehicle, weight and data collected at the landfill
- Assignment change data (e.g. temporary modification to the city owned equipment roster)
- Equipment breakdown and crew change data

The daily outputs of the data collection/reporting phase programs are:

- Daily control information which is tabulated in summary form and stored in special purpose records in the reference files
- A management report which presents weight, cost, and landfill trip information for each city owned collection vehicle

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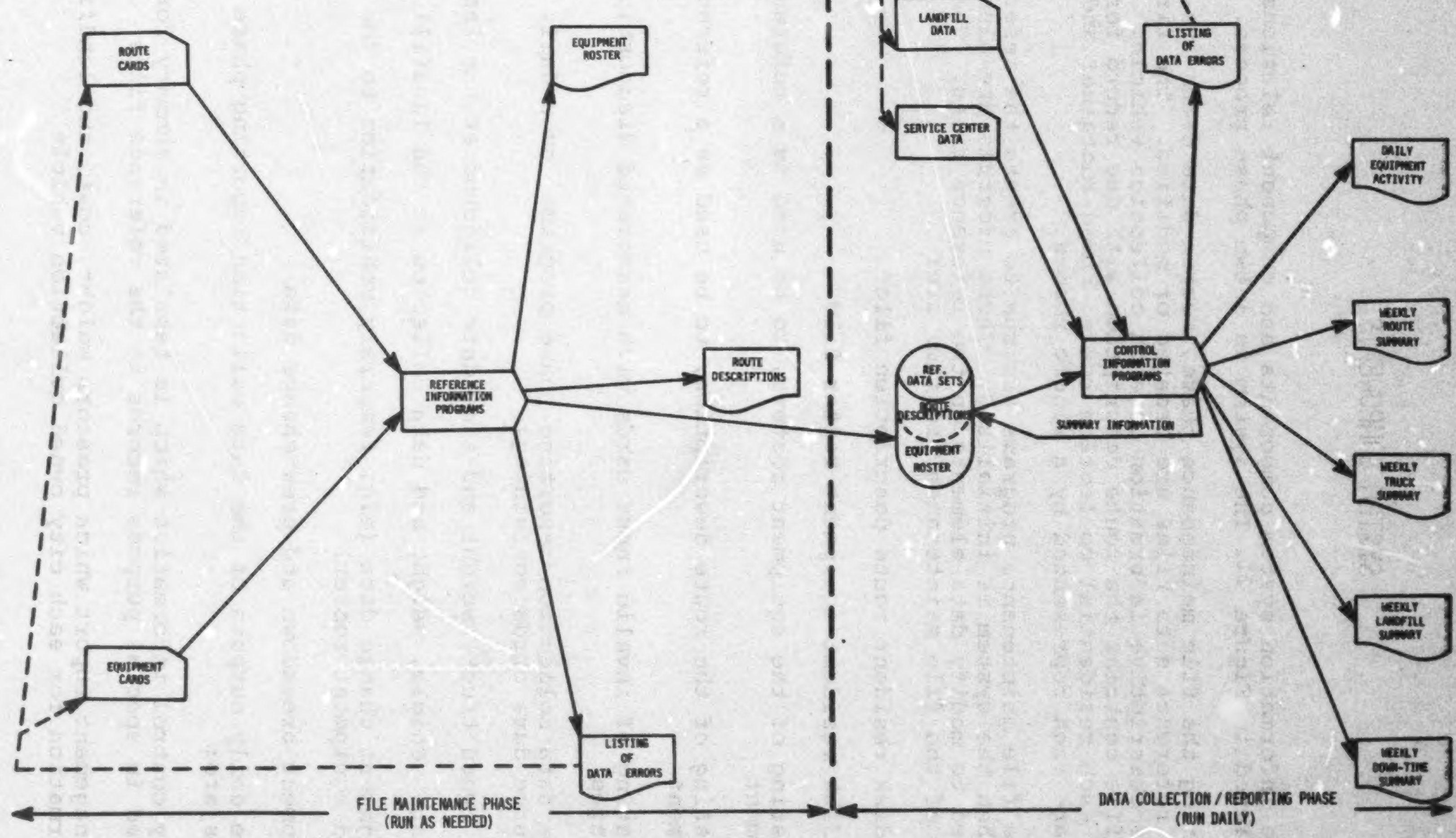
ROUTE CARDS
EQUIPMENT CARDS
REFERENCE INFORMATION PROGRAMS
EQUIPMENT ROSTER
ROUTE DESCRIPTIONS
LISTING OF DATA ERRORS
FILE MAINTENANCE PHASE
(RUN AS NEEDED)
LANDFILL DATA
SERVICE CENTER DATA
LISTING OF DATA ERRORS
REF. DATA SETS
ROUTE DESCRIPTIONS
EQUIPMENT ROSTER
CONTROL INFORMATION PROGRAMS
SUMMARY INFORMATION
DAILY EQUIPMENT ACTIVITY
WEEKLY ROUTE SUMMARY
WEEKLY TRUCK SUMMARY
WEEKLY LANDFILL SUMMARY
WEEKLY DOWN-TIME SUMMARY
DATA COLLECTION / REPORTING PHASE
(RUN DAILY)

SOLID WASTE INFORMATION SYSTEM COMPONENTS

Figure 21

- A management report which presents weight information for privately owned collection vehicles

- A listing of invalid input cards with associated diagnostic messages

The data collection/reporting phase programs, on a weekly basis, read tabulated information from the summary portion of the reference files and produce five management reports. The reports present:

- A weekly summary of weight, cost and landfill trip information for each collection route

- A weekly summary of weight, cost and landfill trip information for each city owned collection vehicle

- A weekly summary of weight and landfill information for privately owned collection vehicles

- A weekly summary of breakdown information for each city owned vehicle

- A weekly summary of costs and weight information for each landfill

In addition to weekly totals, these reports present year-to-date information on selected data elements.

SYSTEM INPUTS

Source data cards are read by the information system programs in five different formats. Route cards and equipment cards are read by the maintenance phase programs. Landfill cards (city and private vehicle) and daily exception cards are read by the reporting phase programs. Each of these data sources is described below.

ROUTE CARDS

Each collection route is described as a set of connected route segments called links. Each link is identified by a starting point called an "A node" and an ending point called a "B node". A given link's B node is the following link's A node. Each link has several attributes. These attributes are represented as data elements in a punched card. Each link is represented by one card and each route by the set of cards corresponding to its links. Link cards in a route set are in order by the occurrence of the link in the route. The format of the route link card is shown in Table 9.

Data are also gathered on fixed container and convoy routes. Route segments are not coded for these routes. Each fixed container or convoy route is represented in the data file by a single record. The format of this route card is also shown in Table 9.

CITY EQUIPMENT CARDS

Each city owned vehicle is represented to the system by a single punched card. The format of this card is shown in Table 9.

CITY VEHICLE LANDFILL CARDS

The information system programs will present control information, concerning city owned collection vehicles, to management on a daily basis. The control data collected and presented daily consist of collection performance data and system cost data. The collection performance data are collected each time a collection vehicle visits a landfill. Each visit is represented by one punched card. The format of this landfill card is shown in Table 10.

PRIVATE VEHICLE LANDFILL CARDS

The information system programs will present control information, concerning privately owned collection vehicles, to management on a daily basis. These data are collected each time a private vehicle visits a landfill. The format of the landfill card is shown in Table 10.

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TABLE 9. INITIALIZATION DATA CARD FORMATS

CARD TYPE	CARD COLUMNS	CONTENTS	REMARKS
Residential Route	2-6	A Node	
	7-11	B Node	
	12-15	Link distance	in feet
	16-18	Route number	001 to 099
	20-22	Number of residential units on the link	
	23-26	Map sheet number	
	27	Street surface	1=paved; 2=unpaved
	28	Street type	1=street, 2=alley
	29-30	Number of containers	
	74-79	Card sequence number	
	80	Card type	'R'
Fixed Container Route	16-18	Route number	100-199
	80	Card type	'R'
Convoy Route	16-18	Route number	200-299
	80	Card type	'R'
Equipment	1-5	Equipment number	
	7	Equipment type	P=packer; M=mother truck; V=private hauler; T=container train; A=alley container; L=land fill equip.
	9-10	Capacity	in cubic yards
	12-13	Year of purchase	
	15	Make	C=Chevrolet; F=Ford; I=International; D=Dodge; G=GMC; O=Other
	17-21	Tare weight	in pounds
	23-25	Mon-Thur route assignment	Landfill equipment assigned to LF1 or LF2
	26-28	Tues-Fri route assignment	
	29-33	Standard daily personnel costs	Dollars and cents
	35-39	Average daily overhead costs	Dollars and cents
	41-45	Average daily maintanance costs	Dollars and cents
	46-50	Convoy daily personnel costs	Dollars and cents
	52-56	Average convoy daily overhead costs	Dollars and cents
	58-62	Average convoy daily maintenance costs	Dollars and cents

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TABLE 10. OPERATIONAL DATA CARD FORMATS

CARD TYPE	CARD COLUMNS	CONTENTS	REMARKS
Landfill	1-4	Time of day	HHMM
	5	AM or PM	'A' or 'P'
	6-11	Date	MMDDYY
	12-16	Equipment number	priv.haulers=99999
	17-21	Gross weight (net wt. for private vehicles)	in pounds
	22	Landfill number	
	23-25	Route assigned (if different from standard assignment)	route nbr
	26-30	Last node collected (applies to packer trucks on residential routes only)	sequence nbr
	80	Card type	'L'
Daily exception	1-6	Date	MMDDYY
	7-11	Equipment number	
	17	Short crew indicator	non-blank=short crew
	18	Out of service indicator	non-blank=out of service
	19-20	Hours out of service	in hours
	80	Card type	'S'

DAILY EXCEPTION CARDS

System performance data are captured each day. These data include:

- Equipment breakdown records
- Deviations from the standard crew size

These data are punched for input to the information system programs. The format of the daily exception card is shown in Table 10.

CHAPTER IV

SYSTEM DATA FILES

The system utilizes two reference data files. These files are disk resident and contain information about the equipment and routes of the Solid Waste Collection System. The files are maintained (created or updated) by the programs of the maintenance phase. They are accessed daily by the programs of the data collection/ reporting phase. (See Figure 21.)

MASTER CITY EQUIPMENT DATA FILE (EQUIPREF)

This file contains one record for each piece of city owned equipment involved in the solid waste collection operation. Each record contains equipment data plus weekly and yearly statistical data on equipment performance. The equipment data portion of each record is essentially the same information as found on the equipment input cards (see Table 9). The file is organized sequentially and is in order by equipment number. The file is created and updated by the Equipment Update program "CSW030".

MASTER ROUTE DATA FILE (RTEMASTER)

This file contains information about the routes traveled by the solid waste collection vehicles. For residential routes there is a record for each route link, while fixed container and convoy routes are represented by a single record each. The record data elements are essentially the same as found on the route input cards (see Table 9). A cumulative residential units field has been added to the residential route links to assist in the reporting of daily performance. Two additional link records, with sequence number 999998 and 999999, have been added to each route to hold the weekly and yearly statistical data. The file is created with indexed sequential organization and, thus, individual route links within a specified route may be accessed directly. Link sequence number and route number form the record key. Fixed container and convoy route records have a pseudo link number of zero to complete the key. The file contains approximately 7,000 records. The Master Route Program creates a tape from the existing file and update cards. This tape is then used to create or rebuild the file.

TEMPORARY DATA FILES

In addition to the two master data files mentioned above, a number of temporary working files are necessary to the operation of the system. These are described as follows:

- Hold Old Route and Hold New Route (UTILITY 1, UTILITY 2)--These files are used in the update process of the Master Route Program. The updated revision of a route is built in the Hold New Route file while a copy of the route in its original form is built in the

Hold Old Route file. If no errors are encountered during the update process, the Hold New Route file is written to the tape. If errors are found, the tape is built from the Hold Old Route file. This interlock mechanism prevents the loss of existing data through update errors.

- Temporary Equipment (TEMPREF)--This file is used in many of the programs in the system when fields of the equipment records are being updated (both data and statistics). In general the individual equipment records are read from the Master Equipment file, updated and placed on the Temporary Equipment file. When all updates are complete, the temporary data is transferred to the Master file. If errors occur, the transfer is inhibited.

- Daily Input (CSWDDATA)--This file is a temporary holding area for the daily landfill and exception data. It is created by the Daily Edit Pass 1 program "CSW 040" after the input data has been thoroughly edited for keypunch errors and coding errors. If no errors are found, this hold file becomes the input to the Sort Utility "CSW 045". During this phase, it is sorted by time-of-day within equipment number. The daily exception cards are given a pseudo time of 0000 which forces them to the front of the data on each peice of equipment. The sorted file is then used as input to the Daily Edit Pass 2 program.

Data file information is summarized in Table 11. A few small files are used to hold summary lines and error lines for subsequent report generation. These files are identified in Table 11.

TABLE 11. DATA FILE SUMMARY

ID	FILE CHARACTERISTICS	RESIDES ON	CREATED BY UPDATED BY	READ BY
RTEMASTER	ISAM,Record size=37 Blocked 10	Disk	ISAMUTIL CSW050 CSW060	MSTRUT CSW050 CSW060
BACKUPRTES	Sequential,Record size=37 Unblocked	Tape	MSTRUT	ISAMUTIL
UTILITY 1	Sequential,Record size=37 Unblocked	Disk	MSTRUT	MSTRUT
UTILITY 2	Sequential,Record size=37 Unblocked	Disk	MSTRUT	MSTRUT
UTILITY 3	Sequential,Record size=54 Unblocked	Disk	MSTRUT	MSTRUT
UTILITY 4	Sequential,Record size=83 Unblocked	Disk	MSTRUT	MSTRUT
TEMPREF	Sequential,Record size=114 Blocked 10	Disk	CSW030 CSW050 CSW060	CSW030 CSW050 CSW060
EQUIPREF	Sequential,Record size=114 Blocked 10	Disk	CSW030 CSW050 CSW060	CSW030 CSW050 CSW060
CSWDDATA	Sequential,Record size=22 Blocked 20	Disk	CSW040 CSW045	CSW045 CSW050
CSWACTVT	Sequential,Record size=79 Blocked 10	Disk	CSW050	CSW050
CSWSUMRY	Sequential,Record size=26 Blocked 20	Disk	CSW050	CSW050

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SYSTEM PROGRAMS

The Solid Waste Management Information System is made up of six computer programs. The programs are written in ANS COBOL as described in IBM manual GC28-6394.

The programs are in two functional groups. The programs which maintain the Master Route and Master Equipment data files are referred to as the File Maintenance Subsystem. The programs which process the daily data cards and produce daily and weekly reports are called Data Collection/Reporting Subsystem. A program system diagram is provided in Figure 22.

FILE MAINTENANCE SUBSYSTEM

Master Route Program "MSTRUT"

- Description--In general this program is a merge of the existing Route Master File with update cards to produce a New Route File on magnetic tape. This tape may then be used to reload the Master Route File. The tape also serves as a backup copy of the Master File. The update cards provide the capabilities of inserting, changing or deleting file records.

  The Master Route File is organized with the route link records of each route in order by sequence number. These routes are then in order by unique route number. The process steps leading to an updated route are as follows:

  (1) The existing route file is read to initialize the input buffer.

  (2) An update card is read.

  (3) If the route number on the update card is less than the route number in the input buffer, the update card is out of order (unless a new route is being added with a route number smaller than the existing lowest route number) and is skipped. If the route number on the update card is greater than the route number in the input buffer the existing route file is written sequentially to the tape file (New Route File) until a route number in the input buffer is equal to or greater than that on the update card. When the two route numbers are equal, the specified route is in update status.

  (4) The merge continues with the route being updated. However, as each link is read from the existing file it is first written to a holding file (Hold Old Route). The route is carefully edited for tolerance or data errors and an updated copy is written to

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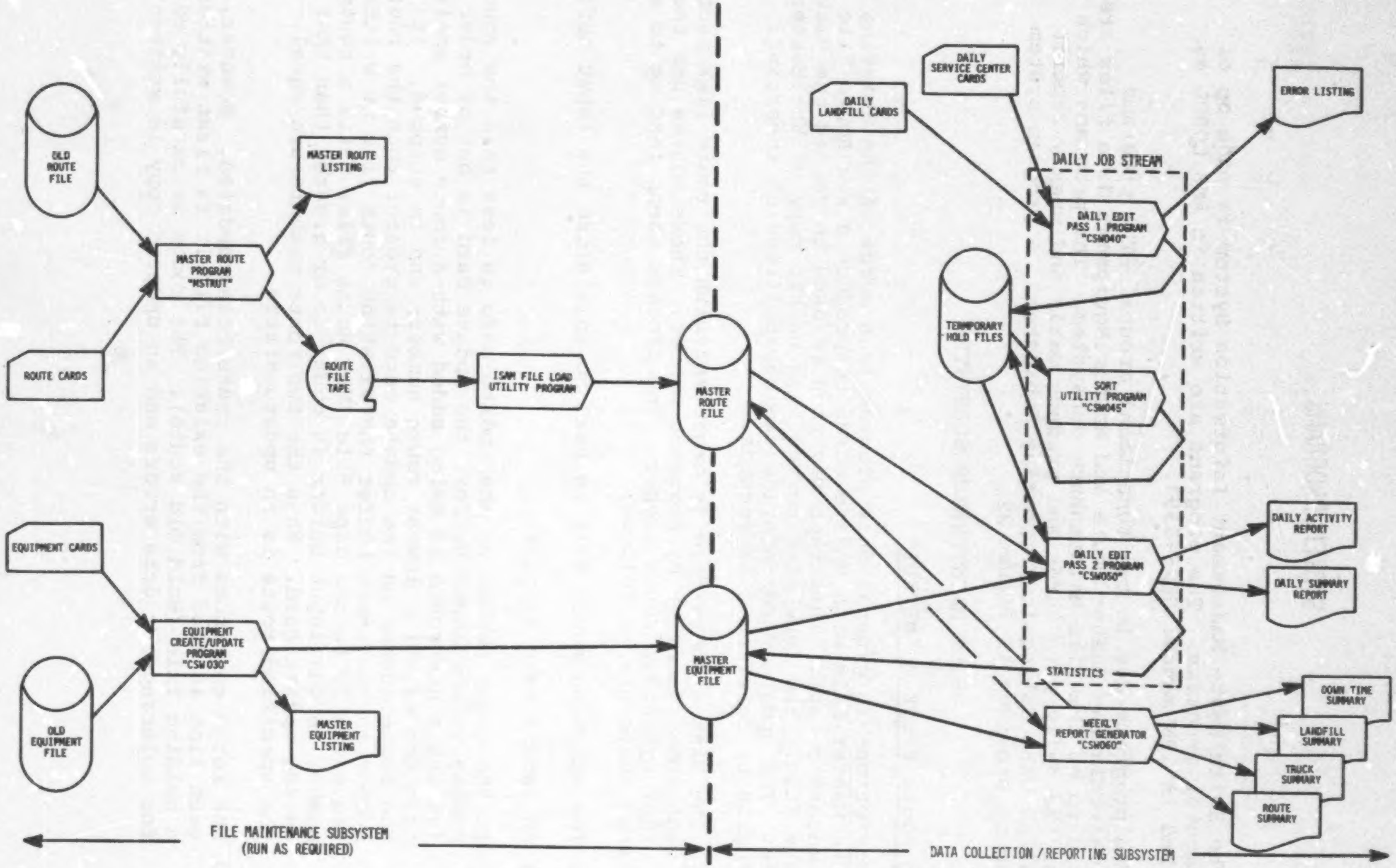
OLD ROUTE FILE
ROUTE CARDS
MASTER ROUTE PROGRAM "MSTRUT"
MASTER ROUTE LISTING
ROUTE FILE TAPE
ISAM FILE LOAD UTILITY PROGRAM
MASTER ROUTE FILE
EQUIPMENT CARDS
OLD EQUIPMENT FILE
EQUIPMENT CREATE/UPDATE PROGRAM "CSW030"
MASTER EQUIPMENT LISTING
MASTER EQUIPMENT FILE
DAILY LANDFILL CARDS
DAILY SERVICE CENTER CARDS
DAILY JOB STREAM
DAILY EDIT PASS 1 PROGRAM "CSW040"
ERROR LISTING
TEMPORARY HOLD FILES
SORT UTILITY PROGRAM "CSW045"
DAILY EDIT PASS 2 PROGRAM "CSW050"
DAILY ACTIVITY REPORT
DAILY SUMMARY REPORT
STATISTICS
WEEKLY REPORT GENERATOR "CSW060"
DOWN TIME SUMMARY
LANDFILL SUMMARY
TRUCK SUMMARY
ROUTE SUMMARY
FILE MAINTENANCE SUBSYSTEM (RUN AS REQUIRED)
DATA COLLECTION / REPORTING SUBSYSTEM

PROGRAM SYSTEM DIAGRAM

Figure 22

(911)

another holding file (Hold New Route). If no errors were found during the edit process, the tape file is written from the updated copy of the route. If errors were found, the route is restored from Hold Old Route. A copy of the Master Route lising report is made only for those routes successfully updated. If an action is taken to a fixed container or convoy route, a report listing the current routes is generated.

In addition to providing the update capability for the Master Route File, this program serves two other purposes. First, running this program with no old route files and using a master route deck of punched cards, will create a tape which may be used to initialize the Master Route File. Second, running the program with the existing Master Route File and no update cards will create a tape containing all the records of the current file. This tape, then, becomes a backup of the Master Route File for that day. It is suggested that such a tape be created once a month to protect against data loss should a failure occur on the direct access device holding the Master Route File.

- Input

  (1) Master Route File

  (2) Update Cards--There are two basic card formats for the Update Cards. The first is used to change an existing route link or to insert a new route link. The format for this type card is the same as for the Route Card described in Table 9. The second type of Update Card is used to delete route links from the file. It's format is:

  Col. 1-5 - Sequence number of first link to delete.

  Col. 6-10 - Sequence number of last link to delete. If only one link is to be deleted, columns 6-10 should be the same as columns 1-5.

  Col. 11-15 - Blank

  Col. 16-18 - Route number

  Col. 19 - Blank

  Col. 20-25 - The word "DELETE"

- Output

  (1) Updated Route File on tape

  (2) Printed reports:

    - Master Route Listing (see Figure 23)
    - Special Error Listing
    - Route Summary (see Figure 23)

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CITY OF WICHITA FALLS
SOLID WASTE DIVISION

MASTER ROUTE LIST

ROUTE 236 RUN DATE 07-15-74
PAGE 008

A NODE	B NODE	LINK DIST	SURF CODE	STRT CODE	NUMBER RES. UNITS	MAP NBR	SEQ NBR
31417	31418	700	P	S	17	109A	130600
31418	31712	90	P	S		109A	130610
31712	33600	255	U	A	11	109A	130620

ROUTE SUMMARY

ROUTE 236 HAS 710 RESIDENTIAL UNITS

MAP SHEETS TRAVERSED BY THIS ROUTE ARE 109A 109B 116D

	STREET		ALLEY		
	PAVED	UNPAVED	PAVED	UNPAVED	TOTAL
COLLECTION DISTANCE	36,950	0	0	800	37,750
NON-COLL. DISTANCE	16,630	0	440	0	17,070
TOTAL DISTANCE	53,580	0	440	800	54,820

COMMERCIAL/CONVOY ROUTE LIST

ROUTE NBR	ROUTE TYPE	NBR OF TRAINS
271	COMMERCIAL	
272	COMMERCIAL	
273	COMMERCIAL	
280	CONVOY	4
281	CONVOY	4

MASTER ROUTE LIST AND ROUTE SUMMARY

Figure 23

- Error Messages--As the existing Master Route File is being updated, each update card is thoroughly edited for common errors. If an error is found, that route is not updated. The error is indicated by a special message found in the right margin of the Master Route List for the errant line. The message format is "**ERROR nn**" where nn is a two digit error code. A list of the error codes is presented in Table 12.

Master Route Load Program

- Description--This program is used to build the disk resident Master Route File from the tape created by the Master Route Program.
- Input--Route File tape.
- Output--New Master Route File on disk.
- Error Messages--None.

City Equipment Update Program "CSW030"

- Description--This program is used in maintenance of the Master City Equipment File to update existing records, add new records or delete old records. It performs a merge of the Master City Equipment File with update cards to produce a new file.

The general sequence of the program is as follows:

(1) Read the existing Master City Equipment File.

(2) Read an Update Card.

(3) Thoroughly edit the Update Card. If errors are found write the appropriate error messages and return to Step 2.

(4) If the Equipment Number from the Master City Equipment File is less than the Equipment Number on the Update Card, write the Equipment Record to a Temporary File, read the next record on the Master City Equipment File and repeat Step 4.

(5) If the Equipment Number from the Master City Equipment File is greater than the Equipment Number of the Update Card, write Update Card to the Temporary File and return to Step 2.

(6) If the two Equipment Numbers are equal, write the Update Card to the Temporary File and return to Step 1.

When all the Update Cards and Master City Equipment File records have been read, and if no edit errors have occurred, the Temporary File is moved to replace the Master City Equipment File. This program can also create a Master City Equipment File by using only the Equipment Deck as input.

TABLE 12. ERROR CODES GENERATED BY MASTER ROUTE PROGRAM "MSTRUT"

ERROR NO.	MEANING
3	Route - Type Indicator invalid
5	Card out of order by sequence number
6	A-Node field not numeric
7	A-Node field not equal to preceeding B-Node field
8	B-Node field not numeric
9	Residential Units not numeric
10	Link Distance not numeric
11	Link Distance out of range (< 10 ft)
12	Street Surface Code invalid
13	Street Type Code invalid

- Input

  (1) Master City Equipment File

  (2) Update Cards--The update transactions of adding a new equipment record or changing an existing one utilize the card format for the City Equipment Card presented in Table 9. The format for the delete transaction card is:

  Col. 1-5 - Equipment number

  Col. 6-11 - The word "DELETE"

- Output

  (1) Updated City Equipment File (if no edit errors were found)

  (2) Written reports:

    - Equipment Update Errors
    - Master City Equipment List (see Figure 24)

- Error Messages--Error messages may be generated as the Update Cards are edited. These messages will be found in the Equipment Update Errors report. The errors must be corrected before the file can be updated. The error messages are listed in Table 13.

DATA COLLECTION/REPORTING SUBSYSTEM

Daily Edit - Pass 1 "CSW040"

- Description--This program is the first of three programs ("CSW040", "CSW045" and "CSW050") which form the daily job stream. It is a simple edit and reformat program which processes the landfill and daily exception data cards. The program reads the cards, edits them, reformats them and writes them on a holding file for the Sort Utility ("CSW045"). If errors are detected, the daily job stream is aborted. The erroneous cards must be corrected. Processing must then be initiated by rerunning "CSW040".

- Input

  (1) Landfill Cards

  (2) Daily Exception Cards

  (3) Operator Response--One of the fields on each of the above cards is the current day's date. The operator will be requested at the console to enter this date. The input date will then be used to compare against the date on the cards for editing purposes and as a date for the reports. This same date is passed as a reformatted record with key of all

```
                                      CITY OF WICHITA FALLS
                                      SOLID WASTE DIVISION

                                      MASTER EQUIPMENT LIST                              RUN DATE 07-15-74
                                                                                              PAGE 1

                                       FIXED CONTAINER/PACKER                                 CONVOY
                                   *********DAILY COSTS*********           *********DAILY COSTS*********
                          STANDARD
EQUIP   EQUIP    TARE      ROUTE     STND.   AVRG.   AVRG.   AVRG.       STND.   AVRG.   AVRG.   AVRG.
 NBR    TYPE    WEIGHT     ASSIG.    PERSO.  OVHD.   MAINT.  TOTAL       PERSO.  OVHD.   MAINT.  TOTAL


3100   M28701   12,000    236 237    243.36  17.10   13.10   273.56      388.12  11.10    4.70   403.92

3101   M28701   12,000    238 241    243.36  17.10   14.00   274.46      391.16  11.10    7.70   409.96

3102   M28731   12,200    240 247    243.36  21.50   16.50   281.36      344.10  11.10   13.30   368.50

3103   M2873G   12,300    244 251    243.36  21.50   17.00   281.86      344.10  11.10   11.80   367.00
```

MASTER EQUIPMENT LIST

Figure 24

TABLE 13. ERROR MESSAGES GENERATED BY THE EQUIPMENT UPDATE PROGRAM "CSW030"

- EQUIP. NUMBER IS NON-NUMERIC (COL. 1-4)
- EQUIP. NUMBER IS OUT OF RANGE (COL. 1-4)
- TRUCK YEAR IS NON-NUMERIC (COL.12-13)
- TRUCK YEAR IS OUT OF RANGE (COL. 12-13)
- PERSONNEL COST IS NON-NUMERIC (COL. 29-33)
- PERSONNEL COST IS OUT OF RANGE (COL. 29-33)
- OVERHEAD COST IS NON-NUMERIC (COL. 35-39)
- OVERHEAD COST IS OUT OF RANGE (COL. 35-39)
- MAINTENANCE COST IS NON-NUMERIC (COL. 41-45)
- MAINTENANCE COST IS OUT OF RANGE (COL. 41-45)
- TRUCK TYPE IS NOT LEGAL CHARACTER (COL. 7)
- TARE WEIGHT IS NON-NUMERIC (COL. 17-21)
- TARE WEIGHT IS OUT OF RANGE (COL. 17-21)
- T OR M TYPE EQUIP. HAS ILLEGAL ROUTE ASSIGNMENT (COL. 23-27)
- T OR M TYPE EQUIP. HAS ILLEGAL TRUCK SIZE (COL. 9-10)
- P, M OR A TYPE EQUIP. HAS NON-NUMERIC TRUCK SIZE (COL. 9-10)
- P, M OR A TYPE EQUIP. HAS OUT OF RANGE TRUCK SIZE (COL. 9-10)
- P OR A TYPE EQUIP. HAS NON-NUMERIC ROUTE ASSIGNMENT (COL. 23-27)
- P OR A TYPE EQUIP. HAS OUT OF RANGE ROUTE ASSIGNMENT (COL. 23-27)
- A TYPE EQUIP. HAS ILLEGAL ROUTE ASSIGNMENT (COL. 23-37)

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zeros, through the Sort Utility and used by Daily Edit - Pass 2 ("CSW050"). The request for the date appears as:

```
ENTER REPORT DATE IN FORMAT MMDDYY
```

A correct reply for March 14, 1974 would be 031474.

- Output

  (1) Save File--The holding file to be used as input to "CSW045".

  (2) Printed reports:

    - Daily Edit Program - 1 (see Figure 25)
    - Daily Edit Program - 1 Summary (see Figure 25)

- Error Messages--The errors output by this program are of two types. The first are those found on the individual input data cards. The error messages are self explanatory and found on the Card Listing Report opposite the card in error. These messages are shown in Table 14. The second type of error is that found in the program itself and whose presence is signalled by a message to the operator's console and an abnormal program stop. The only error of this type possible in this program, occurs when the date entered by the operator contains a non-numeric character. The message displayed is:

```
***DATE ENTERED CONTAINS NON-NUMERIC***
***REFUSE DAILY EDIT PASS 1 CANNOT CONTINUE***
```

Sort Utility "CSW045"

- Description--This program of the daily job stream sorts the reformatted landfill and daily exception records into ascending order by time of transaction within equipment number. During the reformat phase of "CSW040" the daily exception records were assigned a pseudo time of all zeros. In addition, a pseudo record was made up with the current date. This date record was assigned equipment number zero, time zero. After the sort the file will contain the date record followed by the daily exception record and landfill records for the truck with the lowest ID number, followed by daily exception records and landfill records for successively larger truck ID numbers. "CSW045" is the IBM Disk Sort Utility program.

- Input--Save File - generated by "CSW040"

- Output--Save File - sorted as described above

- Error Messages--None

```
                    CITY OF WICHITA FALLS
                    SOLID WASTE DIVISION
                                                  RUN DATE 07-23-74
                                                       PAGE 3

                   DAILY EDIT PROGRAM - 1

          DAILY DATA CARDS                               ERRORS

            LANDFILL CARD
53   1510   P   072374   003100   21640   1   391000
            LANDFILL CARD
54   1530   P   072394   003106   21000   1   292600   DATE FIELD INVALID
            LANDFILL CARD
55   1550   P   072374   003110   19910   1   188430


                   DAILY EDIT PROGRAM - 1
                      PROGRAM SUMMARY

      NUMBER OF CITY LANDFILL CARDS PROCESSED      -  55

      NUMBER OF PRIVATE LANDFILL CARDS PROCESSED   -  40

      NUMBER OF EXCEPTION CARDS PROCESSED          -   4

      TOTAL NUMBER OF CARDS PROCESSED              -  99

      TOTAL ERRORS FOUND                           -   1
```

DAILY ACTIVITY EDIT REPORT

Figure 25

TABLE 14. ERROR MESSAGES GENERATED BY THE DAILY EDIT - PASS 1 "CSW040"

LANDFILL CARD ERROR MESSAGES:

- TIME FIELD INVALID
- AM-PM FIELD INVALID
- DATE FIELD INVALID
- EQUIPMENT NUMBER NOT NUMERIC
- GROSS WEIGHT FIELD NOT NUMERIC
- GROSS WEIGHT FIELD OUT OF TOLERANCE
- LANDFILL NUMBER INVALID
- NODE NUMBER NOT NUMERIC
- NON-STANDARD ROUTE FIELD NOT BLANK AND NOT NUMERIC

DAILY EXCEPTION CARD ERROR MESSAGES:

- EQUIPMENT NUMBER NOT NUMERIC
- DATE FIELD INVALID
- OUT OF SERVICE HOURS NOT NUMERIC
- OUT OF SERVICE HOURS OUT OF RANGE
- OUT OF SERVICE HOURS GREATER THAN ZERO BUT OUT OF SERVICE NOT INDICATED

Daily Edit - Pass 2 "CSW050"

- Description--This program again edits the landfill and daily exception records for errors. The editing is more complex. The first pass ("CSW040") is designed to detect keypunch and coding errors. The errors found by "CSW050" are dependent on information already known by the system and stored on one of the two Master Data Files. For example, the sequence number field of a landfill record cannot be checked for validity until it is known whether the equipment went out on a non-standard route (from the landfill data) or what its standard route assignment is (from the Master Equipment File).

  The program merges the daily collected data (which is in equipment number order) with the Master Equipment File. Editing and statistic gathering are done for each of the following vehicle types: Convoy mother trucks, Packer trucks, Convoy trains, and Landfill equipment. For the mother and packer trucks, if there is no matching data cards, then it is assumed that the truck didn't work and no statistics are gathered. For trains, the only data collected are out of service time from the daily exception card. Finally, for landfill equipment it is assumed that they worked at the landfill of standard assignment unless a landfill card is submitted indicating a change. Out of service time may also be submitted on landfill equipment. After processing and updating the appropriate statistic fields, the Equipment File records are written to a temporary file. Other statistics concerning the equipment's activities by route are gathered and stored on a temporary file for later use in updating the Master Route File's statistics records.

  The merge procedure continues until all of the daily records and Master Equipment File record have been read and processed. An error listing report is generated as errors are found. If no errors are detected no error listing is generated and the program moves into a report generation phase.

  During this phase the daily statistics are used to produce the daily reports. In addition, the Master Equipment File is rewritten from the temporary file to update the statistics on the file. The appropriate statistic records of the Master Route File are also updated.

- Input

  (1) Save File - daily input records from "CSW045"
  (2) Master Equipment File
  (3) Master Route File - accessed randomly

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- **Output**

  (1) Master Equipment File - updated if no errors found
  (2) Master Route File - updated if no errors found
  (3) Printed reports:

  - Daily Edit Program - 2 (error listing) - only if errors found
  - Daily Equipment Activity (see Figure 26)
  - Daily Equipment Summary (see Figure 27)

- **Error Messages**--There are two types of error messages generated in this program, those found in the edit phase and listed on the error listing and those displayed at the operator's console. Messages of the first type are listed in Table 15. These errors require that the card in error be corrected and the daily job stream be rerun beginning with "CSW040". There is only one error of the second type. It occurs when the program finds an empty data set for daily input data. The message displayed is:

```
***DAILY DATA INPUT EMPTY***
***CSW050 CANNOT CONTINUE***
```

Weekly Report Generator - "CSW060"

- **Description**--The daily programs produce activity statistics which are stored in the Master File records. Program "CSW060" uses these statistics to produce four weekly management reports. Each report is produced independently by sequencing through the appropriate file and picking up the needed statistic fields. As the Weekly Operations Summary By Route is produced, the weekly statistic fields in each route statistic record are reset to zero and the records are rewritten to the file. When producing the Weekly Landfill Summary, the Equipment File is read and written to a temporary file. After the report is complete the temporary file is read, the weekly statistic fields zeroed, and then restored to the Master Equipment File.

- **Input**

  (1) Master Equipment File

  (2) Master Route File

  (3) Operator Query--The reports generated by this program require the starting and ending dates for the week. These will be included in the page heading for each report. The operator will be queried to enter the dates with the following messages appearing at the console:

```
                        CITY OF WICHITA FALLS
                        SOLID WASTE DIVISION
                                                       PAGE 1

                       DAILY EQUIPMENT ACTIVITY
                          07-23-74 TUESDAY

        EQUIP EQUIP  RTE DUMP  NET     RES   LAST  MAINT OTHER TOTAL  EXCEPTIONS
         NBR  TYPE   NBR TIME  WGT     UNIT  LINK  COST  COST  COST   CREW   TRK

   (1)  3100  M2870I  37 0930  8,040    220 379440

        3100  M2870I  37 1115  7,860    181 382110

        3100  M2870I  37 1510  9,640    330 391000 13.10 17.10 273.56

        3101  M2870I  41 1110 11,400    296 312440

        3101  M2870I  41 1530 12,110    334 313160 14.00 17.10 274.46  X

   (2)  3201  M2870I 201 0930  8,790

        3201  M2870I 201 1330  9,240               42.00 18.00  275.20

   (3)  3201  M2870I 156 2030 14,010               10.00  5.00  175.00

   (4)  3482  L3271G LF1

        3483  L3271G LF2


        (1)  PACKER TRUCKS ON RESIDENTIAL ROUTES
        (2)  CONTAINER SERVICE TRUCKS ON CONVOYS
        (3)  CONTAINER SERVICE TRUCK ON FIXED CONTAINER ROUTE
        (4)  LANDFILL EQUIPMENT
```

DAILY EQUIPMENT ACTIVITY REPORT

Figure 26

```
                     CITY OF WICHITA FALLS
                     SOLID WASTE DIVISION
                                                 PAGE 3

                    DAILY EQUIPMENT SUMMARY
                      07-23-74 TUESDAY

                                   NBR   AVERAGE   AVERAGE             COST
EQUIP   EQUIP    ROUTE   TOTAL     OF    WEIGHT    LBS PER   CONVOY    PER
 NBR    TYPE      NBR    WEIGHT   DUMPS  PER DUMP  RES UNIT   COST     TON

3100    M2870I    237    25,540     3      8,513       35    273.56   21.42

3101    M2870I    241    23,510     2     11,755       37    274.46   23.35

3102    M2873I    247    21,800     3      7,267       31    281.36   25.81

PRIV                     10,240     2      5,120
```

DAILY EQUIPMENT SUMMARY

Figure 27

TABLE 15. ERROR MESSAGES GENERATED BY THE DAILY EDIT - PASS 2 "CSW050"

ERROR - CARD NBR ** CONTAINS INVALID EQUIPMENT NUMBER

ERROR - CARD NBR ** CONTAINS INVALID ROUTE NUMBER

ERROR - CARD NBR ** CONTAINS INVALID NODE NUMBER

ERROR - CARD NBR ** CONTAINS GROSS WEIGHT LESS THAN TARE WEIGHT

ERROR - EQUIPMENT NUMBER *** HAS SEQUENCE NODES OUT OF ORDER BY TIME CHECK CARD **

```
***ENTER STARTING REPORT DATE-FORMAT MM-DD-YY
***ENTER ENDING REPORT DATE-FORMAT MM-DD-YY
```

Note that the hyphen ("-") is a required part of the reply. Thus the proper replies for the six day work week of March 25, 1974 would be:

```
03-25-74
03-30-74
```

- Output

  (1) New Master Equipment File - weekly statistic fields reset
  (2) New Master Route File - weekly statistic fields reset
  (3) Printed reports:

  - Weekly Operations Summary By Route (see Figure 28)
  - Weekly Operations Summary By Truck (see Figure 29)
  - Weekly Landfill Summary (see Figure 30)
  - Weekly Down Time Summary (see Figure 31)

- Error Messages--None

CITY OF WICHITA FALLS
SOLID WASTE PROJECT

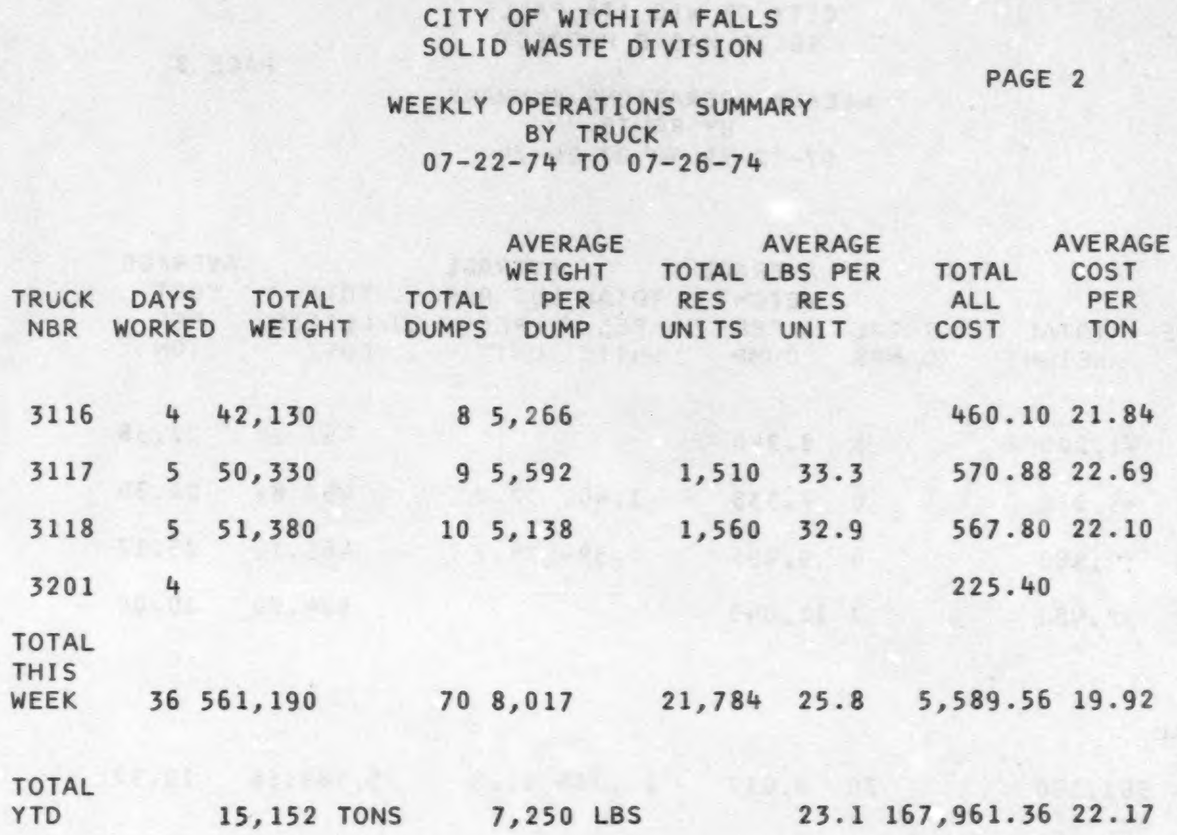
PAGE 2

WEEKLY OPERATIONS SUMMARY
BY ROUTE
07-22-74 TO 07-26-74

ROUTE NBR	TOTAL WEIGHT	TOTAL DUMPS	AVERAGE WEIGHT PER DUMP	TOTAL RES UNITS	AVERAGE LBS PER RES UNIT	TOTAL COLLECTION COST	AVERAGE COST PER TON
61	41,200	5	8.240			461.12	22.38
62	45,210	6	7,535	1,402	32.2	458.88	20.30
63	39,980	4	9,995	1,394	28.7	463.19	23.17
201	52,480	7	12,040			524.80	10.00
TOTAL THIS WEEK	561,190	70	8,017	21,784	25.8	5,589.56	19.92
TOTAL YTD	15,152 TONS	2090	7,250 LBS		23.1	167,961.36	22.17

WEEKLY ROUTE SUMMARY REPORT

Figure 28



```
                       CITY OF WICHITA FALLS
                       SOLID WASTE DIVISION
                                                      PAGE 2
                     WEEKLY OPERATIONS SUMMARY
                             BY TRUCK
                       07-22-74 TO 07-26-74

                                AVERAGE          AVERAGE          AVERAGE
                                WEIGHT    TOTAL  LBS PER   TOTAL   COST
TRUCK  DAYS    TOTAL     TOTAL   PER       RES     RES      ALL     PER
 NBR  WORKED  WEIGHT     DUMPS  DUMP     UNITS    UNIT     COST     TON

 3116    4   42,130          8 5,266                      460.10 21.84

 3117    5   50,330          9 5,592      1,510   33.3    570.88 22.69

 3118    5   51,380         10 5,138      1,560   32.9    567.80 22.10

 3201    4                                                225.40

TOTAL
THIS
WEEK    36  561,190         70 8,017     21,784   25.8  5,589.56 19.92

TOTAL
YTD         15,152 TONS      7,250 LBS            23.1 167,961.36 22.17
```

WEEKLY TRUCK SUMMARY REPORT

Figure 29

CITY OF WICHITA FALLS
SOLID WASTE DIVISION

WEEKLY LANDFILL SUMMARY
07-22-74 TO 07-26-74

LANDFILL NUMBER	EQUIPMENT NUMBER	EQUIPMENT TYPE	WEIGHT THIS WEEK IN TONS		WEIGHT YEAR TO DATE IN TONS
1	3116	M2871I	21.1		611.9
1	3117	M2871I	25.2		738.4
1	3118	M2873I	25.7		742.7
1	PRIV		18.2		503.6
	TOTALS FOR LANDFILL 1		280.6		7,576.1
	DISPOSAL COST PER TON THIS WEEK		$ 3.10	YTD	$ 3.08

WEEKLY LANDFILL REPORT

Figure 30

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CITY OF WICHITA FALLS
SOLID WASTE DIVISION

WEEKLY DOWN TIME SUMMARY
07-22-74 TO 07-26-74

EQUIPMENT NUMBER	EQUIPMENT TYPE	HRS. DOWN THIS WEEK	HRS. DOWN YEAR TO DATE
3101	M2870I	1	1
3111	P2468G	11	41
3116	M2871I	0	7
TOTAL		17	302

WEEKLY DOWN TIME REPORT

Figure 31

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MANAGEMENT REPORTS

The solid waste information system is designed to collect and present important management information, but only important information. It is also designed to use only a small amount of daily computer time. The information system produces three types of reports:

- Formatted listings of the route and equipment master data files
- Daily management control reports
- Weekly management summary reports

Figure 32 illustrates the master route listing. For residential routes, the listing contains one detail line for each route link. The route number, page number and run data are produced at the top of each page for easy reference. The last page of each route list contains summary information on route distance, map sheets and residential units. For fixed container and convoy routes, a separate report is provided listing the route numbers and route types.

Figure 33 illustrates the master equipment listing. The listing contains one detail line for each piece of equipment. The equipment type column indicates the type of truck, its capacity, its year of purchase and its make. See Table 9 for an explanation of the codes. The route assignments column contains a Monday-Thursday and Tuesday-Friday assignment for standard route assignments. Convoy train data are listed for completeness only. Cost fields may be filled in but cost statistics will be kept by convoy only in the record for the mother truck. All data presented on this report are stored in the equipment master file and are referenced by the programs when producing the daily and weekly reports.

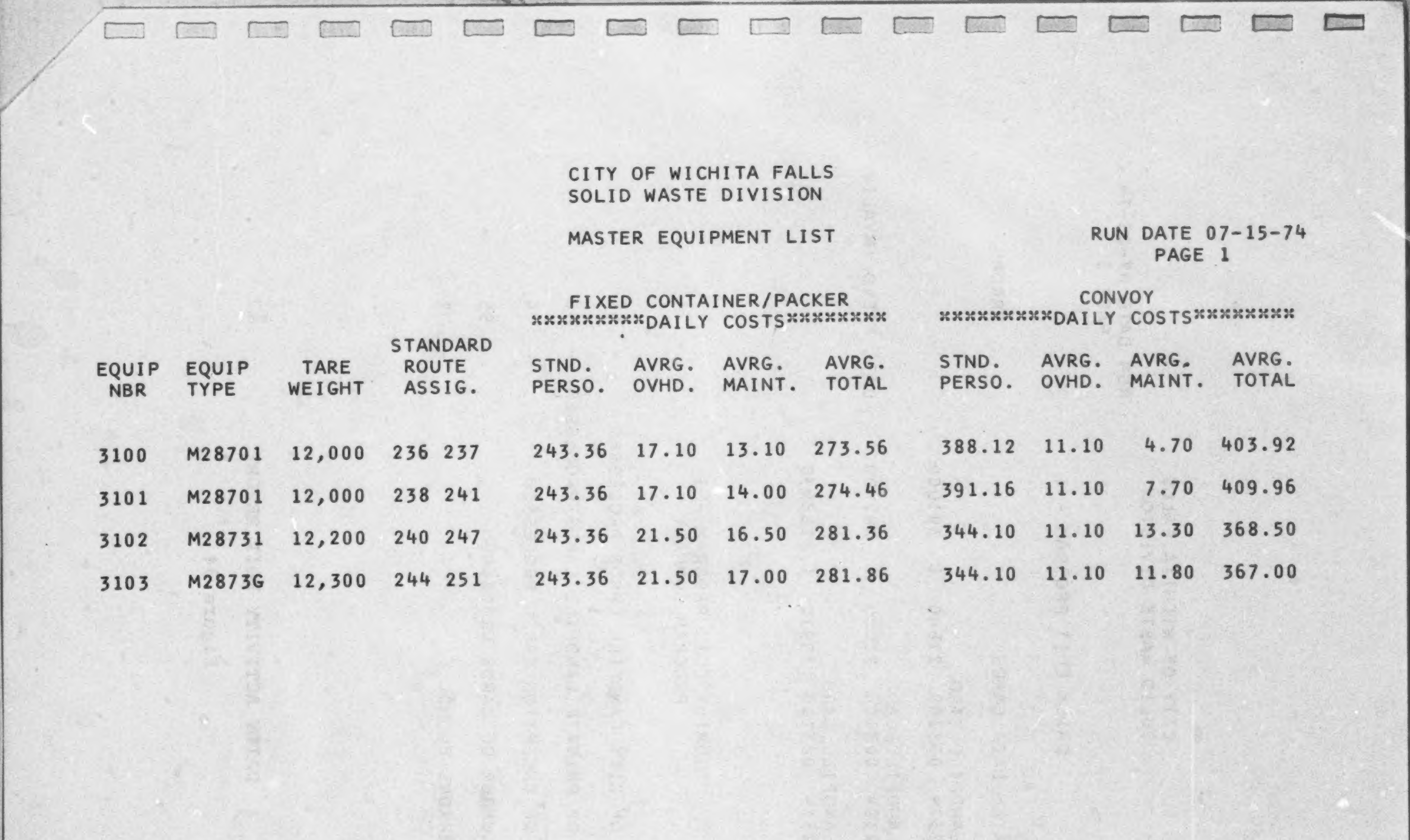
The daily processing produces three reports. The edit report, see Figure 34, presents a list of all data cards processed with accompanying error messages as needed. Figure 35 illustrates the daily equipment activity report. The report contains one detail line for each landfill trip. The lines are in equipment number order. The last line for each truck on a specific route presents cost information. Figure 36 illustrates the daily equipment summary report. Each truck on a specific route is represented by a detail line. Average weight and average cost information are provided for management comparison.

The weekly reports present operational data summarized by route, by vehicle and by landfill. The route summary is shown in Figure 37. The truck summary is shown in Figure 38. Figure 39 illustrates the landfill summary. A summary of equipment down times is shown in Figure 40.

```
                   CITY OF WICHITA FALLS
                   SOLID WASTE DIVISION

                     MASTER ROUTE LIST
                        ROUTE 236          RUN DATE 07-15-74
                                                   PAGE 008

  A        B       LINK   SURF   STRT     NUMBER      MAP     SEQ
 NODE     NODE     DIST   CODE   CODE   RES. UNITS    NBR     NBR

31417    31418     700     P      S         17        109A   130600

31418    31712      90     P      S                   109A   130610

31712    33600     255     U      A         11        109A   130620


                    **ROUTE SUMMARY**

ROUTE 236 HAS 710 RESIDENTIAL UNITS

MAP SHEETS TRAVERSED BY THIS ROUTE ARE 109A 109B 116D


                       STREET                 ALLEY
                   PAVED   UNPAVED      PAVED   UNPAVED     TOTAL

COLLECTION DISTANCE 36,950    0            0      800        37,750

NON-COLL. DISTANCE  16,630    0          440        0        17,070

TOTAL DISTANCE      53,580    0          440      800        54,820

              COMMERCIAL/CONVOY ROUTE LIST
       ROUTE NBR      ROUTE TYPE      NBR OF TRAINS

          271         COMMERCIAL

          272         COMMERCIAL

          273         COMMERCIAL

          280         CONVOY                4

          281         CONVOY                4
```

MASTER ROUTE LIST AND ROUTE SUMMARY

Figure 32



```
                                    CITY OF WICHITA FALLS
                                    SOLID WASTE DIVISION

                                    MASTER EQUIPMENT LIST                    RUN DATE 07-15-74
                                                                                  PAGE 1

                                    FIXED CONTAINER/PACKER                      CONVOY
                                 *********DAILY COSTS********       *********DAILY COSTS********
                         STANDARD
EQUIP  EQUIP    TARE     ROUTE     STND.   AVRG.   AVRG.   AVRG.    STND.   AVRG.  AVRG.   AVRG.
 NBR   TYPE     WEIGHT   ASSIG.    PERSO.  OVHD.   MAINT.  TOTAL    PERSO.  OVHD.  MAINT.  TOTAL

3100   M28701   12,000   236 237   243.36  17.10   13.10   273.56   388.12  11.10   4.70   403.92

3101   M28701   12,000   238 241   243.36  17.10   14.00   274.46   391.16  11.10   7.70   409.96

3102   M28731   12,200   240 247   243.36  21.50   16.50   281.36   344.10  11.10  13.30   368.50

3103   M2873G   12,300   244 251   243.36  21.50   17.00   281.86   344.10  11.10  11.80   367.00
```

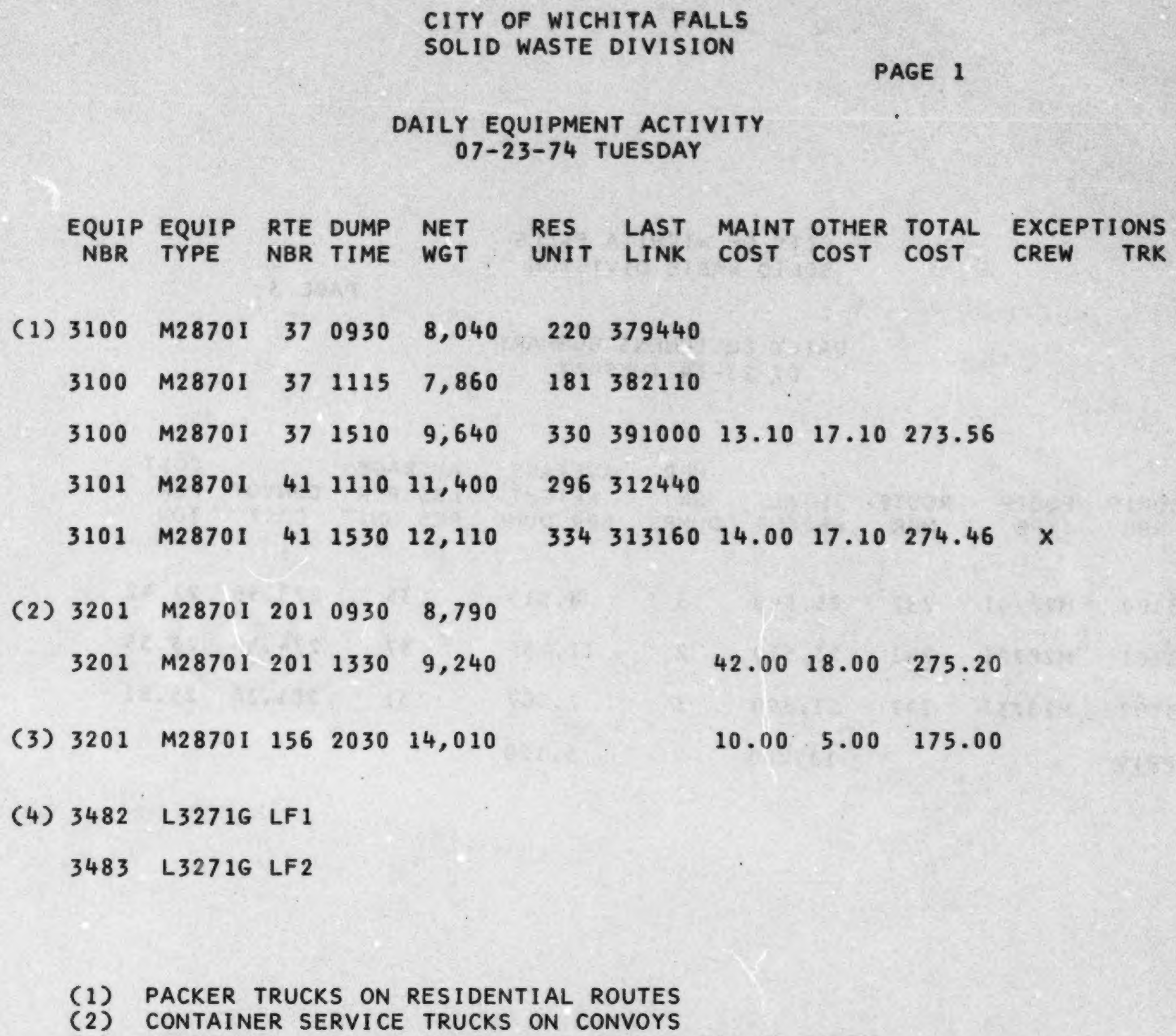
MASTER EQUIPMENT LIST

Figure 33

```
                         CITY OF WICHITA FALLS
                         SOLID WASTE DIVISION
                                                      RUN DATE 07-23-74
                                                          PAGE 3

                        DAILY EDIT PROGRAM - 1

                  DAILY DATA CARDS                             ERRORS

                   LANDFILL CARD
53   1510   P   072374   003100   21640   1   391000
                   LANDFILL CARD
54   1530   P   072394   003106   21000   1   292600      DATE FIELD INVALID
                   LANDFILL CARD
55   1550   P   072374   003110   19910   1   188430


                        DAILY EDIT PROGRAM - 1
                           PROGRAM SUMMARY

        NUMBER OF CITY LANDFILL CARDS PROCESSED      -  55

        NUMBER OF PRIVATE LANDFILL CARDS PROCESSED   -  40

        NUMBER OF EXCEPTION CARDS PROCESSED          -   4

        TOTAL NUMBER OF CARDS PROCESSED              -  99

        TOTAL ERRORS FOUND                           -   1
```

DAILY ACTIVITY EDIT REPORT

Figure 34



```
                        CITY OF WICHITA FALLS
                        SOLID WASTE DIVISION
                                                   PAGE 1

                      DAILY EQUIPMENT ACTIVITY
                         07-23-74 TUESDAY

    EQUIP EQUIP  RTE DUMP  NET    RES  LAST   MAINT OTHER TOTAL  EXCEPTIONS
     NBR  TYPE   NBR TIME  WGT    UNIT LINK   COST  COST  COST   CREW   TRK

(1) 3100  M2870I  37 0930  8,040   220 379440

    3100  M2870I  37 1115  7,860   181 382110

    3100  M2870I  37 1510  9,640   330 391000 13.10 17.10 273.56

    3101  M2870I  41 1110 11,400   296 312440

    3101  M2870I  41 1530 12,110   334 313160 14.00 17.10 274.46   X

(2) 3201  M2870I 201 0930  8,790

    3201  M2870I 201 1330  9,240              42.00 18.00  275.20

(3) 3201  M2870I 156 2030 14,010              10.00  5.00  175.00

(4) 3482  L3271G LF1

    3483  L3271G LF2


    (1)  PACKER TRUCKS ON RESIDENTIAL ROUTES
    (2)  CONTAINER SERVICE TRUCKS ON CONVOYS
    (3)  CONTAINER SERVICE TRUCK ON FIXED CONTAINER ROUTE
    (4)  LANDFILL EQUIPMENT
```

DAILY EQUIPMENT ACTIVITY REPORT

Figure 35

CITY OF WICHITA FALLS
SOLID WASTE DIVISION

PAGE 3

DAILY EQUIPMENT SUMMARY
07-23-74 TUESDAY

EQUIP NBR	EQUIP TYPE	ROUTE NBR	TOTAL WEIGHT	NBR OF DUMPS	AVERAGE WEIGHT PER DUMP	AVERAGE LBS PER RES UNIT	CONVOY COST	COST PER TON
3100	M28701	237	25,540	3	8,513	35	273.56	21.42
3101	M28701	241	23,510	2	11,755	37	274.46	23.35
3102	M28731	247	21,800	3	7,267	31	281.36	25.81
PRIV			10,240	2	5,120			

DAILY EQUIPMENT SUMMARY

Figure 36

(120)

CITY OF WICHITA FALLS
SOLID WASTE PROJECT

PAGE 2

WEEKLY OPERATIONS SUMMARY
BY ROUTE
07-22-74 TO 07-26-74

ROUTE NBR	TOTAL WEIGHT	TOTAL DUMPS	AVERAGE WEIGHT PER DUMP	TOTAL RES UNITS	AVERAGE LBS PER RES UNIT	TOTAL COLLECTION COST	AVG. COST PER TON
61	41,200	5	8,240			461.12	22.38
62	45,210	6	7,535	1,402	32.2	458.88	20.30
63	39,980	4	9,995	1,394	28.7	463.19	23.17
201	52,480	7	12,040			524.80	10.00
TOTAL THIS WEEK	561,190	70	8,017	21,784	25.8	5,589.56	19.92
TOTAL YTD	15,152 TONS	2090	7,250		23.1	167,961.36	22.17

WEEKLY ROUTE SUMMARY REPORT

Figure 37

CITY OF WICHITA FALLS
SOLID WASTE DIVISION

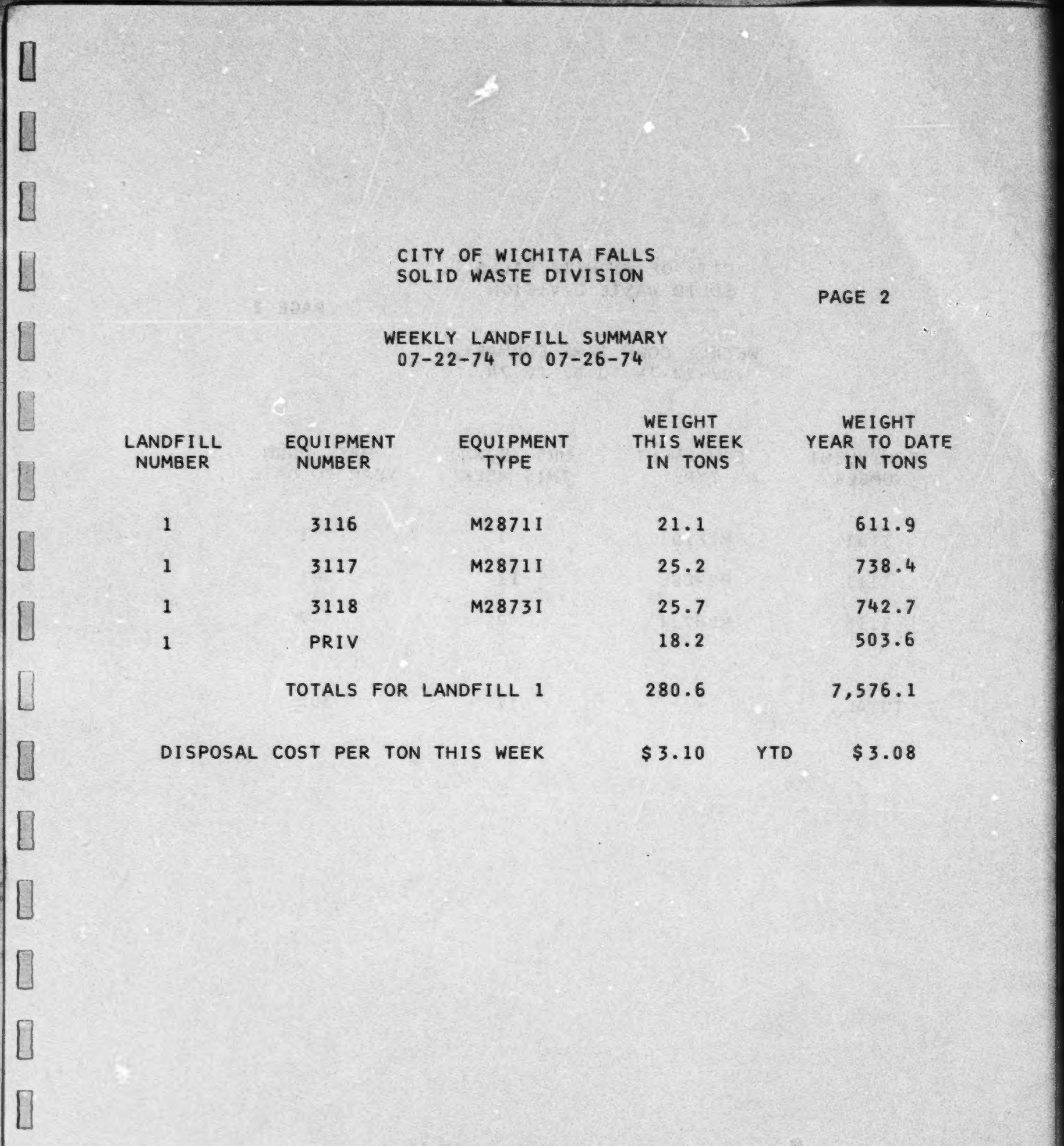
PAGE 2

WEEKLY OPERATIONS SUMMARY
BY TRUCK
07-22-74 TO 07-26-74

TRUCK NBR	DAYS WORKED	TOTAL WEIGHT	TOTAL DUMPS	AVERAGE WEIGHT PER DUMP	TOTAL RES UNITS	AVERAGE LBS PER RES UNIT	TOTAL ALL COST	AVG. COST PER TON
3116	4	42,130	8	5,266			460.10	21.84
3117	5	50,330	9	5,592	1,510	33.3	570.88	22.69
3118	5	51,380	10	5,138	1,560	32.9	567.80	22.10
3201	4						225.40	
TOTAL THIS WEEK	36	561,190	70	8,017	21,784	25.8	5,589.56	19.92
TOTAL YTD		15,152 TONS		7,250		23.1	167,961.36	22.17

WEEKLY TRUCK SUMMARY REPORT

Figure 38



CITY OF WICHITA FALLS
SOLID WASTE DIVISION

PAGE 2

WEEKLY LANDFILL SUMMARY
07-22-74 TO 07-26-74

LANDFILL NUMBER	EQUIPMENT NUMBER	EQUIPMENT TYPE	WEIGHT THIS WEEK IN TONS		WEIGHT YEAR TO DATE IN TONS
1	3116	M28711	21.1		611.9
1	3117	M28711	25.2		738.4
1	3118	M28731	25.7		742.7
1	PRIV		18.2		503.6
	TOTALS FOR LANDFILL 1		280.6		7,576.1
DISPOSAL COST PER TON THIS WEEK			$3.10	YTD	$3.08

WEEKLY LANDFILL REPORT

Figure 39

CITY OF WICHITA FALLS
SOLID WASTE DIVISION

WEEKLY DOWN TIME SUMMARY
07-22-74 TO 07-26-74

EQUIPMENT NUMBER	EQUIPMENT TYPE	HRS. DOWN THIS WEEK	HRS. DOWN YEAR TO DATE
3101	M2870I	1	1
3111	P2468G	11	41
3116	M2871I	0	7
TOTAL		17	302

WEEKLY DOWN TIME REPORT

Figure 40

CHAPTER VII

DATA COLLECTION PROCEDURES

The information system programs will process a small amount of daily data pertaining to landfill activity and equipment performance. These data will be collected and recorded each day. The data will be keypunched from the recording forms then processed by the information system programs. The programs will edit all data for errors and will produce appropriate error listings as needed.

The purpose of this chapter is to present procedures which will insure an orderly and accurate collection of the daily data.

CITY EQUIPMENT LANDFILL DATA COLLECTION

Data collected at each landfill include truck number, landfill number, dump time, gross weight and the sequence number of the last route element collected by the truck. The tare weight of each vehicle is stored in the equipment master file, thus the truck will not be weighed when leaving the landfill. The information will be recorded on the data collection form shown in Figure 41.

The completed forms will be taken to Sanitation Department headquarters where they will be validated. The forms will then be delivered to the City Computer Center for keypunching and verifying. The punched cards will be read and processed by the daily edit pass 1 program. All cards will be listed. Each detected error will be identified by an appropriate error message. The edit tests and the associated error messages are listed in Table 15.

PRIVATE EQUIPMENT LANDFILL DATA COLLECTION

All private vehicles entering a landfill will be weighed as they enter and again as they leave. The scale operator will record the date, entering weight, empty weight and city permit number (if the vehicle is operated by a commercial collector) on the data collection form illustrated in Figure 41.

The completed forms will be taken to Sanitation Department headquarters where the private hauler net weights will be calculated and entered on the forms. The completed forms will then be delivered to the City Computer Center for keypunching and verifying. The punched cards will be read and processed by the daily edit pass 1 program. All cards will be listed. Each detected error will be identified by an appropriate error message. The edit tests and the associated error messages are listed in Table 16.

CITY OF WICHITA FALLS
SOLID WASTE LANDFILL FORM

TIME	A/P	DATE	EQUIP. NBR.	GROSS WEIGHT *	FILL	LAST NODE COLLECTED	PRIVATE GROSS WT.	PRIVATE TARE WT.	NON-STND ROUTE

* PRIV for private vehicles
** Net for private vehicles

LANDFILL DATA COLLECTION FORM

Figure 41

TABLE 16. LANDFILL CARD EDIT TESTS AND ERROR MESSAGES

DATA ELEMENT	COLUMNS	EDIT TEST	ERROR MESSAGE
Time of Day	1-4	Hour must be less than 13 Minute must be less than 60	TIME FIELD INVALID
AM - PM	5	Must be A or P	AM - PM FIELD INVALID
Date	6-11	Must match date entered by console operator	DATE FIELD INVALID
Equipment ID	12-16	Must be numeric	EQUIPMENT NUMBER NOT NUMERIC
		Must match number on master file	CARD NBR XX CONTAINS INVALID EQUIPMENT NBR*
Gross Weight	17-21	Must be numeric	GROSS WEIGHT FIELD NOT NUMERIC
		Must be greater than tare weight	CARD NBR XX CONTAINS GROSS WT LESS THAN TARE WT*
		Must be less than 30,000	GROSS WEIGHT FIELD OUT OF TOLERANCE
Landfill ID	22	Must be 1, 2 or 3	LANDFILL NUMBER INVALID
Node Number	23-28	Must be numeric	NODE NUMBER NOT NUMERIC
		Must match a number on the assigned route in the master route file	CARD NBR XX CONTAINS INVALID NODE NBR*
		Must be farther down route than node number on previous dump for the route	EQUIPMENT NUMBER XXX HAS SEQUENCE NODES OUT OF ORDER BY TIME. CHECK CARD XX*

* Message generated by Edit Pass 2. All other messages generated by Edit Pass 1.

DAILY EXCEPTION DATA COLLECTION

Exception information is generated by several different activities. It is recorded on special forms by a clerk at the Sanitation Department headquarters. The form is illustrated in Figure 42.

Two exception conditions will be recorded. If a truck goes out a man short, an "X" is placed in column 17 to indicate this exception condition. If a truck breaks down or is out of service for some other reason, an "X" is placed in column 18. The number of hours out of service is entered in columns 19 and 20.

The completed forms will be delivered daily to the City Computer Center for keypunching and verifying. The punched cards will be read and processed by the daily edit pass 1 program. All cards will be listed. Each detected error will be identified by an appropriate error message. The edit tests and the associated error messages are listed in Table 17.

CITY OF WICHITA FALLS
SOLID WASTE EXCEPTION FORM

DATE							EQUIP. NBR.					(X) SHORT CREW	(X) OUT OF SERV	HOURS OUT	

DAILY EXCEPTION DATA COLLECTION FORM

Figure 42

TABLE 17. SERVICE CENTER CARD EDIT TESTS AND ERROR MESSAGES

DATA ELEMENT	COLUMNS	EDIT TEST	ERROR MESSAGE
Date	1-6	Must match date entered by console operator	DATE FIELD INVALID
Equipment	7-11	Must be numeric Must match number on master file	EQUIPMENT NUMBER NOT NUMERIC CARD NBR XX CONTAINS INVALID EQUIP NBR*
Hours Out of Service and Indicator	19-20	Must be numeric Must be less than 20 If greater than zero, out of service indicator must be filled in	OUT OF SERVICE HOURS NOT NUMERIC OUT OF SERVICE HOURS OUT OF RANGE OUT OF SERVICE HOUR GREATER THAN ZERO BUT OUT OF SERVICE NOT INDICATED

* Message generated by Edit Pass 2. All other messages generated by Edit Pass 1.

μσ1480
SW-150c.1